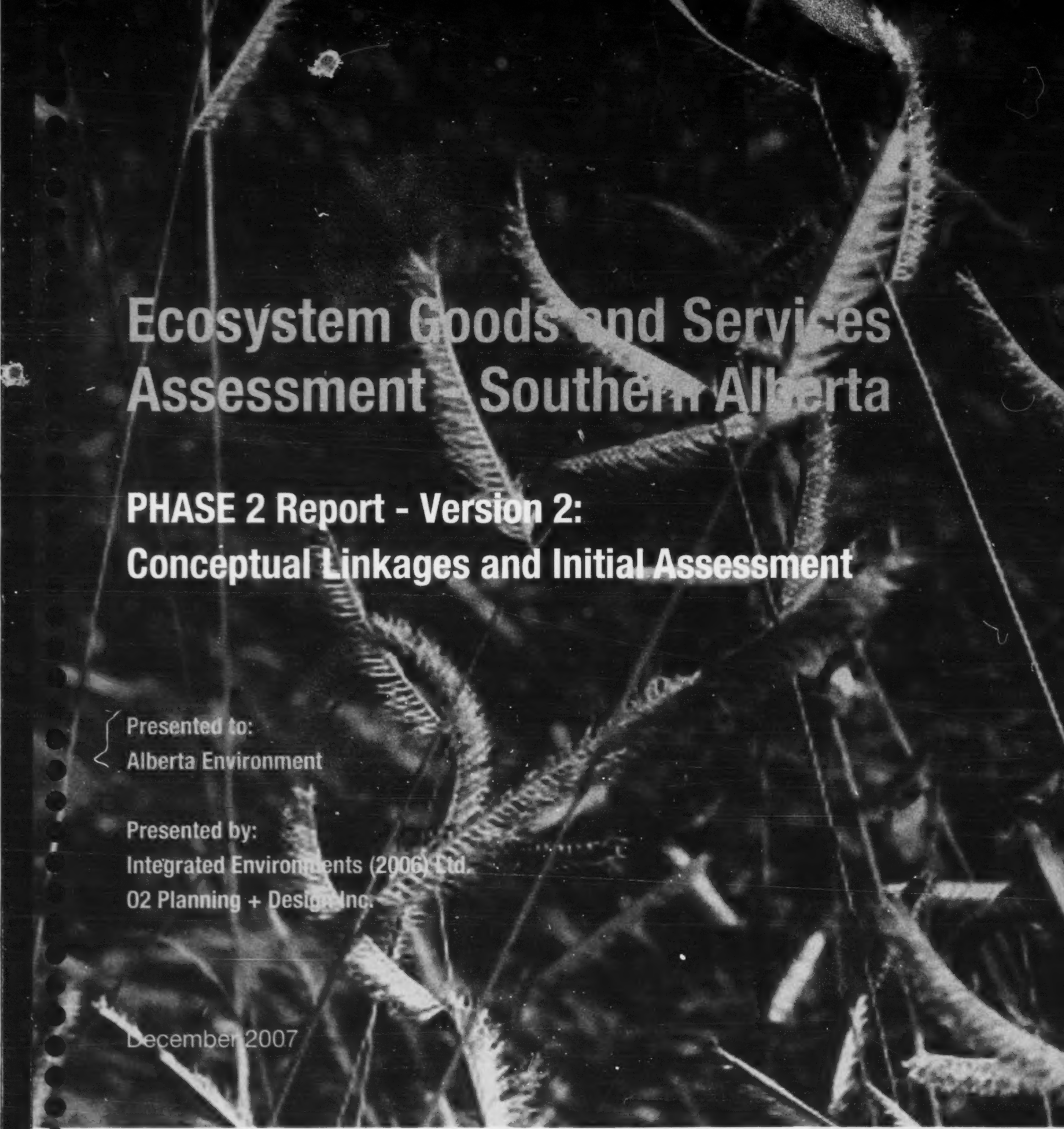

Ecosystem Goods and Services Assessment - Southern Alberta

PHASE 2 Report - Version 2: Conceptual Linkages and Initial Assessment

Presented to:
Alberta Environment

Presented by:
Integrated Environments (2006) Ltd.
02 Planning + Design Inc.

December 2007

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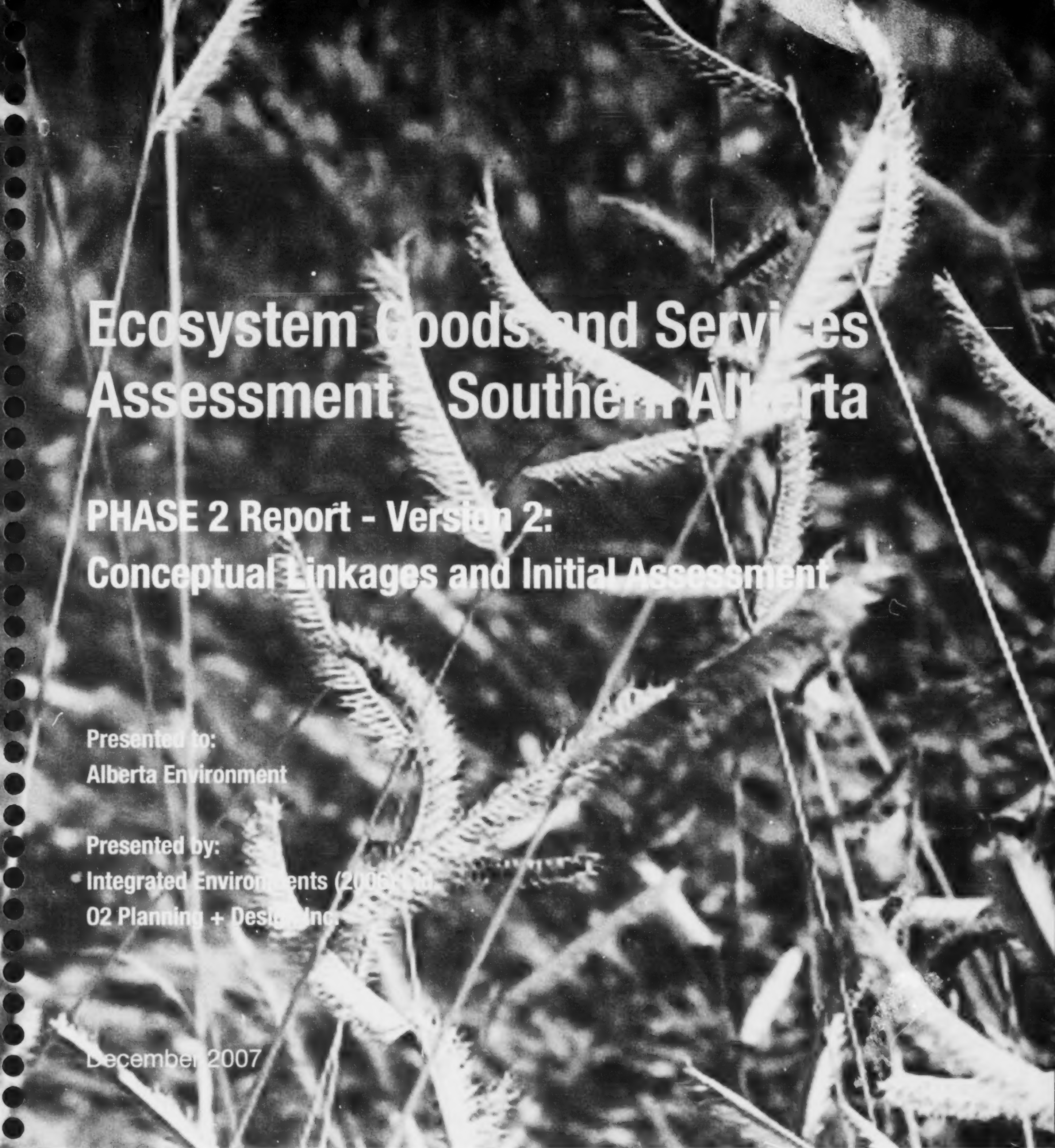

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Alberta
Environment

Integrated Environments
[illegible] • Negotiation • Management

O2 PLANNING DESIGN
Landscape Architecture, Urban + Environmental Planning

ISBN: 978-0-7785-7368-5
ISBN: 978-0-7785-7369-2
Website: www.gov.ab.ca/env/

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Acknowledgements

This report was jointly completed by Integrated Environments (2006) Ltd. and O2 Planning + Design Inc. Contributors to the report included the following individuals:

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Preamble

The purpose of the ecosystem goods and services assessment is to support the development of the Southern Alberta Landscapes: Meeting the Challenges Ahead (SAL) regional strategy.

The SAL regional strategy will deliver societal consensus about the level of environmental quality that is desirable and attainable for southern Alberta landscapes. It will also identify the resource and natural assets worth protecting, forces driving landscape change, issues and opportunities, and priorities for action. Recommendations will be based on sound analysis of the current state of the environment and strategic trends and will be integrated with regional planning initiatives. The strategy will be delivered through a consensus-based process that engages stakeholders, First Nations and the general public. The regional strategy is being developed to help achieve a sustainable environment and a high quality of life in southern Alberta, given the massive economic development occurring in the region.

The geographical scope of the SAL region includes the Alberta portions of the South Saskatchewan River Basin, the Grassland Natural Region, and the Cypress Hills (see Figure i-1). This area is approximately 17% of the province, and includes about 60% of Alberta's population. The SAL region hereafter is referred to as southern Alberta.

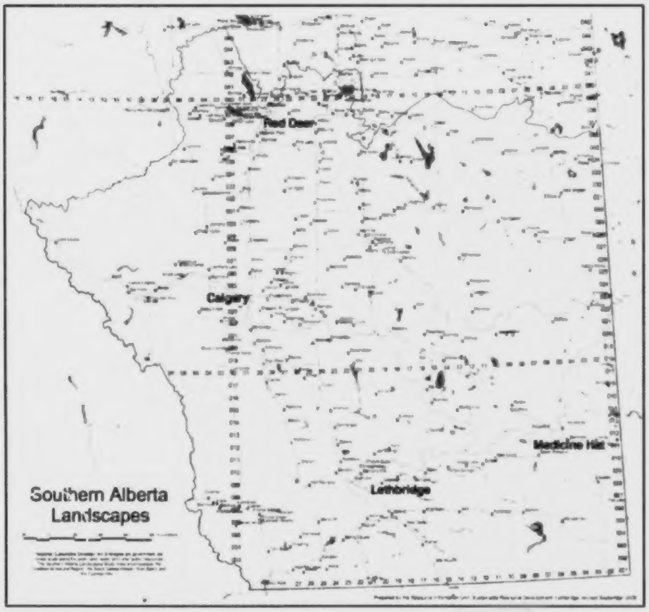


Figure i: Map of the EGS Assessment Area

The ecosystem goods and services assessment will produce an inventory of the natural assets that exist within southern Alberta, and identify the ecosystem goods and services that are subsequently provided. In addition, the assessment will include the following: a description of the role of the ecosystem services in relationship to the maintenance of the assets and the production of the goods, a qualitative evaluation of the relative importance of the ecosystem services to southern Alberta, and the impact that anthropogenic activity has on the services.

Once the assessment is complete the desired information will be mapped based on the assets and the goods and services that these assets build and maintain. The maps will then be used as visual tools to assist those drafting the regional strategy in understanding and determining portion and/or spatial pattern of landscapes should remain relatively undisturbed to sustain the delivery of ecosystem goods and services in southern Alberta.

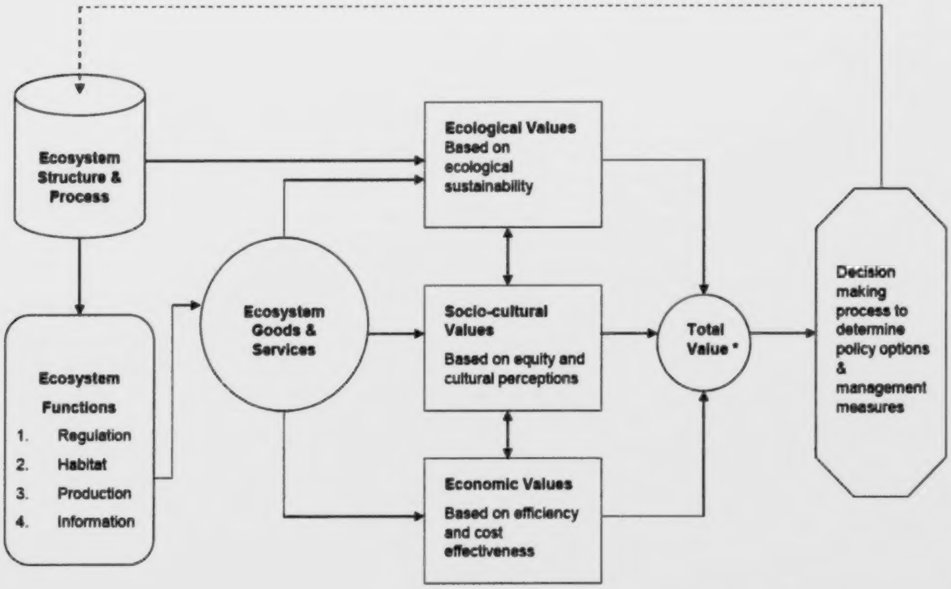
Prior to commencing this project, Alberta Environment conducted research to determine what approach or conceptual framework would be most appropriate. The conceptual framework and methodology created for the Australian Ecosystem Services Project, "Natural Assets" was selected for various reasons (Ecosystem Services Project, 2003, n.d.). The following paragraphs explain these reasons.

First, the conceptual framework outlines the role of ecosystem services in maintaining natural assets, and in supporting the production of goods and services in the region. This framework encourages one to look in at entire landscapes and ecosystems, and the ecological processes occurring in them, in a different way so that new problems and new opportunities can be revealed.

Second, the methodology used to produce the inventory of ecosystem goods and services, along with the lessons learned, were clearly documented enabling the Project Team to follow a process that had been put to the test elsewhere. In addition, the methodology allowed the Project Team to produce the information in a format that would be transferable to the spatial analysis and mapping process.

Third, Alberta Environment already had a large portion of the data required for the project, reducing the amount of information and data gathering that would have been otherwise required. However, as a result, some aspects of the assessment were driven largely by data availability and how the data had been categorized within Alberta Environment's database.

Ecosystem goods and services assessment is a relatively new area of study for Alberta Environment. It is anticipated that additional research on an appropriate framework for integrated assessment and valuation of ecosystem functions, goods and services is required. Figure ii outlines a framework that Alberta Environment could potentially use as a starting point for integrated assessments.


Ecosystem Structure & Process
Ecosystem Functions
1. Regulation
2. Habitat
3. Production
4. Information
Ecosystem Goods & Services
Ecological Values
Based on ecological sustainability
Socio-cultural Values
Based on equity and cultural perceptions
Economic Values
Based on efficiency and cost effectiveness
Total Value *
Decision making process to determine policy options & management measures

Source: de Groot, Wilson & Boumans, 2002

Figure ii: A framework for integrated assessment and valuation of ecosystem functions, goods and services

The *Ecosystem Goods and Services Assessment – Southern Alberta Phase 2 Report: Conceptual Linkages and Initial Assessment* primarily focuses on the ecological, and to a lesser extent, social components of an integrated assessment. Economic values were not considered at this time. Alberta Environment anticipates that future initiatives will incorporate all three values as part of a complete and integrated assessment.

This document (*Version 2* of the *Ecosystem Goods and Services Assessment- Southern Alberta, Phase 2 Report, December 2007*) was revised as a result of recommendations made through a customized peer review process (*Review of Alberta Environment's Ecosystem Goods and Services Assessment- Southern Alberta Phase 2 Report, Management and Solutions in Environmental Science, August 2007*). The peer review provided comments on the main elements of the March 2007, EGS Assessment, as well as opinions, additional perspective and recommendations on topics the Review Team felt were important.

The colour schemes displayed throughout this report have been adjusted to accommodate those readers who are colour-blind and are consistent with colours selected for the spatial analysis and mapping process.

1.0

1.0 Executive Summary

Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life (Daily, 1997). These services provide us with valuable economic goods, are essential for the ongoing maintenance of critical life-support systems and confer a wide range of highly valued non-market benefits. The importance of the world's ecosystem services is substantial. Costanza et al. (1997) estimated their value at US$33 trillion per year, about 1.8 times current global gross national product (GNP).

Evaluations of the importance of ecosystem goods and services in Alberta are in their early stages. In southern Alberta, Alberta Environment is supporting an ecosystem goods and services (EGS) assessment. The purpose of the project is to identify what ecosystem goods and services are important to southern Alberta and how they help sustain the region's vibrant economy and quality of life.

The objectives of the EGS Assessment are to: a) inform people about ecosystem goods and services and how they are important to economic production in southern Alberta, b) help people understand how land use decisions and human activities impact these services, c) determine what landscape patterns are required to sustain the ongoing delivery of ecosystem goods and services and, d) undertake a gap analysis to identify directions for further study and investigation.

The following research questions guided the EGS Assessment:

- *How do ecosystem services support the maintenance of natural and anthropogenic assets?*
- *How do ecosystem services support input to the production of goods?*
- *How does the expansion of anthropogenic assets affect the capacity of the natural assets to provide ecosystem services, and the capacity of the natural assets to produce goods?*
- *How does the condition of natural assets affect the quantity and quality of services they provide?*
- *How can the relative importance of each ecosystem service be assessed?*

The EGS Assessment used an approach and methodology similar to the Australian Ecosystem Services Project. The first step was to develop a conceptual model of the linkages (strong, moderate or weak) between groups of assets, ecosystem services and goods. This was followed by the preparation of a series of Excel spreadsheets to address the aforementioned research questions. The individual Excel spreadsheets were combined to produce a ranking of the overall importance of the 20 ecosystem services in southern Alberta.

Key findings of the EGS Assessment are:

- A total of 20 ecosystem services were assessed as to their importance in producing goods or maintaining natural assets in southern Alberta. The ecosystem services were categorized into four types: regulating, supporting, provisioning, and cultural/aesthetic services. The latter group of services are important in that they capture a wide variety of non-market benefits associated with the conservation of natural assets;

- The conceptual model shows that strong linkages exist between natural assets (native prairie, forest and aquatic assets) and regulating and supporting services. Natural assets, agricultural assets and other anthropogenic assets are also important to provisioning services. Provisioning services (water, food, raw materials and genetic resources) are also important inputs to the production of goods in the primary and secondary sectors of the southern Alberta economy. Cultural services are most important to the production of goods in the tertiary sector of the economy and producing cultural and aesthetic goods;

- A series of linked spreadsheet models was developed to demonstrate that changes to the amount and distribution of natural assets affect the type, quantity, and quality of ecosystem services. In turn, the sustainability of goods produced by ecosystem services is affected. Expansion of anthropogenic assets at the expense of natural cover types negatively affects the ability of ecosystems to produce a wide range of goods and in the long term requires substantial external inputs (e.g. fuel, fertilizer etc.) to offset the loss;

- The 20 ecosystem services are ranked as to their relative importance in southern Alberta. The six services considered to be most important are biological control, erosion control and sediment retention, water supply, water regulation, nutrient cycling and disturbance regulation. Although the assessment considered each service independently, many services are inter-related and have a high degree of dependence and integrated function;

- Independent of the overall ranking of ecosystem services, the current understanding and knowledge of ecosystem services in southern Alberta were considered. Knowledge of the function and process of ecosystem services was highest for recreation, habitat/refugia, water regulation, erosion control and sediment retention, raw materials, food production and primary production. Conversely, knowledge of genetic resources, pollination and gas regulation is least understood; and,

- Key themes emerging from the gap analysis include: 1) the need for standardized methodologies and approaches to EGS Assessment; 2) the need to incorporate economic valuation of market and non-market benefits associated with EGS; 3) the need to review the results of the assessment in a public forum; 4) the need to couple the results of the EGS Assessment with spatially explicit modelling and planning to address the issues of what and where to develop; and 5) the need to link technical EGS assessments and policy instruments for EGS protection into the broader policy development and decision making framework for land-use planning and resource allocation in southern Alberta.

2.0 Introduction

Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life (Daily, 1997). They provide goods of economic value to human beings, the ongoing maintenance of critical life-support systems and confer a wide range of intangible cultural, spiritual, aesthetic and other non-market benefits. The importance of these services to current and future human welfare is substantial. Costanza et al. (1997) estimates the economic value of the world's ecosystem services and natural capital at US$33 trillion per year, about 1.8 times current global gross national product (GNP).

Interest in assessing the world's ecosystem goods and services (EGS) is considerable. The Millennium Ecosystem Assessment was a four year effort (2001 – 2005) involving more than 1300 scientists in 95 countries to assess the consequences of ecosystem change to human welfare (Millenium Ecosystem Assessment, 2005). Ecosystem goods and services assessments have also been undertaken at the country level. Initiated in 1999, the Australian Ecosystem Services Project is evaluating ecosystem services in six regions of the country. Led by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Ecosystem Services Project has a budget of $2 million and involves a wide range of scientists, academics, resource managers, governments and community representatives (Cork, Proctor, Shelton, Abel, & Binning, 2002; Ecosystem Services Project, n.d.). Evaluations of the contribution of Canada's ecosystem services and natural capital have been undertaken in the boreal forest, the Mackenzie River watershed and the settled areas of the country (Anielski & Wilson, 2003, 2007; Olewiler, 2004). Anielski and Wilson (2007) have estimated the value of ecosystem services functioning within the Mackenzie River watershed are worth more than 10 times the value of the GDP at $448.3 billion per year (Anielski & Wilson, 2007). Other major EGS initiatives are underway at the Gund Institute for Ecological Economics at the University of Vermont, the International Union for the Conservation of Nature (IUCN), and the World Resources Institute.

2.1 Project Purpose

The purpose of the ecosystem goods and services assessment is to support the development of the Southern Alberta Landscapes: Meeting the Challenges Ahead (SAL) regional strategy.

The SAL regional strategy will deliver societal consensus about the level of environmental quality that is desirable and attainable for southern Alberta landscapes. It will also identify the resource and natural assets worth protecting, forces driving landscape change, issues and opportunities, and priorities for action. The strategy will be delivered through a consensus-based process that engages stakeholders, First Nations and the general public. It is being developed to help achieve a sustainable environment and a high quality of life in southern Alberta, given the massive economic development occurring in the region.

The ecosystem goods and services assessment will produce an inventory of the natural assets that exist within southern Alberta, and identify the ecosystem goods and services that are subsequently provided. In addition, the assessment will include the following: a description of the role of the ecosystem services in relationship to the maintenance of the assets and the production of the goods, a qualitative evaluation of the relative importance of the ecosystem services to southern Alberta, and the impact that anthropogenic activity has on the services.

Once the assessment is complete the desired information will be mapped based on the assets and the goods and services that these assets build and maintain. The maps will then be used as visual tools to assist those drafting the regional strategy in understanding and determining portion and/or spatial pattern of landscapes should remain relatively undisturbed to sustain the delivery of ecosystem goods and services in southern Alberta.

2.2 Objectives

The broad objectives of the EGS Assessment are to:

- Define what ecosystem goods and services are and why they are important to maintaining the quality of life in southern Alberta;
- Provide an understanding of the value of high quality ecosystems in relation to economic production in southern Alberta, and the possible consequences of land use decisions, (i.e.. the relative impact of human activities on the supply of ecosystem services);
- Highlight the relationship between the condition of an ecosystem (e.g. relatively pristine versus heavily modified) and the ecosystem services it supplies;
- Help determine the portion and/or spatial pattern of landscapes that should remain relatively undisturbed in southern Alberta in order to sustain the delivery of ecosystem goods and services; and,
- Undertake a gap analysis identifying additional areas of investigation and future directions for ecosystem goods and services assessment.

2.3 Project Approach

The following is a broad overview to the procedures and methods used in the EGS Assessment. Specific methods, where relevant, are discussed in sections of the report that follow.

The EGS Assessment made extensive reference to the process undertaken for the Ecosystem Services Project in Australia, but was modified for the southern Alberta context (Ecosystem Services Project, 2003, n.d.).

Key steps in the project approach are as follows:

- Lists of ecosystem services, goods and assets were identified;

- Research questions were finalized relative to understanding the relationship between ecosystem services, goods and natural and anthropogenic assets in southern Alberta;

- Individual spreadsheets were prepared to qualify the relationships posed by the research questions; and,

- An overall summary spreadsheet was prepared to summarize the importance of ecosystem services in southern Alberta.

2.3.1 *Identify Key Ecosystem Services, Goods and Assets*

The first step was to derive a list of ecosystem services, goods and natural/anthropogenic assets (see Appendix 9-1). These were then used in all subsequent analyses; sources of information are as follows:

- The list of natural and anthropogenic assets considered in the EGS Assessment originated from Alberta Environment's spatial information database and ALCES® modelling analysis pertaining to natural regions of southern Alberta. Input from a third party review of this assessment conducted by Management and Solutions in Environmental Science was also incorporated (MSES, 2007);

- The list of ecosystem services for southern Alberta was adapted from a variety of sources (Anielski & Wilson, 2003, 2007; Costanza et al., 1997; de Groot, Wilson, & Boumans, 2002; Ecosystem Services Project, n.d.; Farber et al., 2006; Havstad et al., 2007; Millenium Ecosystem Assessment, 2005; Olewiler, 2004); and,

- The list of goods was derived from a social and economic assessment completed for southern Alberta (Global Training Inc., 2004).

2.3.2 *Develop Research Questions Regarding the Importance of Ecosystem Goods and Services in southern Alberta*

Once the list of ecosystem goods, services and natural/anthropogenic assets had been prepared, a number of research questions were posed to assess the importance of ecosystem goods and services in southern Alberta. These questions arose from the project terms of reference provided by Alberta Environment and are summarized as follows:

- Explain and summarize how the ecosystem services support the maintenance of each asset (both natural and anthropogenic);

- Explain and summarize how the ecosystem services support input to production of the relevant goods;

- Explain and summarize the relationship between the condition of the natural assets and the quantity and quality of services they provide; and,

- Provide the decision criteria and rank the relative importance of each ecosystem service for each natural and anthropogenic asset.

2.3.3 *Qualify the Relationship Between Ecosystem Services, Goods and Natural and Anthropogenic Assets*

Spreadsheets were then prepared in Microsoft Excel to address each research question. Relative importance values in response to each research question were qualified in terms of high, moderate, and low value. Colours were assigned to each value in each spreadsheet to aid in visual analysis of the results.

The assessment of these relative values is based on the review of the available relevant literature and the professional opinion and expertise of the project team. Each category of high, moderate and low was assigned on the following basis:

- A high value was assigned if a strong relationship or dependence was believed to exist between both variables, or if there was good understanding and knowledge in support of the assignment of the value. (e.g. the service of soil formation is very important for the continued maintenance and existence of mixed grass prairie);
- A moderate value was assigned if the relationship or dependence of both variables was neither considered high nor low. (e.g. non-market recreational opportunities are of moderate importance to goods produced from the wholesale/retail sector); and,
- A low value was assigned if a weak relationship or dependence was believed to exist between both variables (e.g. the service of aesthetic enjoyment of functioning ecological systems and the production of oil and gas).

The assessment is considered preliminary and provides an opening basis for discussion and further refinement in a wider public forum. The utility of using a spreadsheet approach is that values can be readily changed and used in simulation or "what-if" exercises as part of a broader consultative exercise.

A list of spreadsheets and their respective table number by each research question is provided in Table 2-1 (following).

Table 2-1: Summary of Excel Spreadsheets Used to Analyze the Importance of Ecosystem Goods and Services in Southern Alberta

Research Question	Analysis	Report Section	Table Number
Explain and summarize how the ecosystem services support the maintenance of each asset (both natural and anthropogenic)	Importance of ecosystem services to the maintenance of assets	4.1	4-1
	Importance of assets to provide ecosystem services	Appendix	9-5
Explain and summarize how the ecosystem services support input to production of the relevant goods	Importance of ecosystem services to the production of goods	4.2	4-2
Explain and summarize the relative impact of expanding anthropogenic assets on the capacity of the natural assets to continue to provide ecosystem services, and the capacity of the natural assets to continue to produce the goods	Impact of expanding anthropogenic assets on the capacity of natural assets to provide ecosystem services and goods	4.3	Fig 4-1, 4-2, 4-3, 4-4
Explain and summarize the relationship between the condition of the natural assets and the quantity and quality of services they provide	Condition of the asset and the quantity of ecosystem services	4.4	4-3, 4-4
Provide the decision criteria and rank the relative importance of each ecosystem service for each natural and anthropogenic asset	Importance of ecosystem services at the margin relative to the production of goods	Appendix	9-28

Table 2-1 cont'd: Summary of Excel Spreadsheets Used to Analyze the Importance of Ecosystem Goods and Services in Southern Alberta

Research Question	Analysis	Report Section	Table Number
	Importance of ecosystem services at the margin relative to the maintenance of assets	Appendix	9-29
	Ability to manage assets to provide ecosystem services	Appendix	9-30
Provide the decision criteria and rank the relative importance of each ecosystem service for each natural and anthropogenic asset	Relative importance (H, M, L) of each services considering the following: • importance of the service to production of goods • importance of the service to the maintenance of assets • importance of the service at the margin • ability to manage the asset for the service • overall ranking	Appendix	9-7 to 9-26
Availability of knowledge related to the service in question	Considers current state of knowledge regarding the service in a particular asset. Does not include availability or quality of data	Appendix	9-31

2.3.4 *Rank the Relative Importance of Ecosystem Services*

Similar to the Australian Ecosystem Services Project, the relative importance (high, moderate, low) of each ecosystem service for each natural and anthropogenic asset in southern Alberta was determined by considering the following criteria:

- The importance of the service to the production of goods;
- The importance of the service to the maintenance of assets;

- Relative importance at the margin (the impact of a small change in status of a service on the production of a good or maintenance of an asset); and,
- Manageability (the ability to manage the asset to ensure the delivery of the service).

In addition, an assessment of the state of knowledge of the service in each asset was considered and given a separate ranking. The assessment of the state of knowledge was based on the literature review of Phase 1 and the professional opinion of the project team. This assessment should be refined through further review by knowledgeable specialists with expertise in ecosystem function, processes and services and will result in continuous improvement to the assessment.

A combined ranking of the importance of each ecosystem service in a given asset was determined through a percentile determination of the sum of each individual cell values to give an overall value of low, moderate or high. Reference notes were also placed in each cell regarding assumptions and comments of the evaluation.

2.4 Limitations to the Assessment

As this is the first time that an assessment of ecosystem goods and services has been completed in southern Alberta, and little data was available, the results of this assessment are considered preliminary in nature. The report is intended to elicit further discussion, review and refinement in a wider public forum. Therefore the results should be viewed as an initial effort rather than a definitive conclusion. It is very likely that the evaluations presented in this report will change during this process.

The following limitations framed the extent of the assessment:

- Decisions on the relative importance of ecosystem services were made based on professional judgment of the project team. Additional analysis and review is required involving a wider forum of professionals with expertise in a wide range of subject areas;
- There was no intent to incorporate any spatial analysis into this phase of the project. This could be done at a later phase, in conjunction with other modelling efforts such as ALCES®;
- There was no attempt made to include economic data in order to quantify the importance of ecosystem goods and services at this phase of analysis;
- The analysis of the impact of expansion of anthropogenic assets on ecosystem services is relative as no weighting factors, such as economic importance, were assessed at this time; and,
- There was no involvement of the public in this initial assessment of ecosystem goods and services.

Additional areas for research and investigation are provided in a gap analysis that identifies priorities and next steps for further action (see Section 5).

2.5 Organization of the Report

The remainder of the Phase 2 Version 2 report is organized as follows:

Section 3 is an introduction to ecosystem goods and services, explaining what they are and why they are important to southern Alberta. It also describes natural and anthropogenic assets and how these are important to the provision of ecosystem services and human derived goods. A conceptual model of the linkages is presented describing the relationship between natural and anthropogenic assets, ecosystem services, and goods produced in southern Alberta.

Section 4 provides a description of the role of ecosystem goods and services in southern Alberta. It describes the role of ecosystem services in relation to the maintenance of natural and anthropogenic assets and how they are important to the provision of goods. It also describes, in a qualitative fashion, the impact of the expansion of anthropogenic assets on the capacity of natural assets to provide ecosystem services and goods. The relationship of the condition of natural assets (e.g. fragmented, intact) and their ability to provide ecosystem services is discussed. Finally, the relative importance of ecosystem services in southern Alberta is discussed.

Section 5 presents a gap analysis of what is required for further assessment of ecosystem goods and services in southern Alberta.

Section 6 is a summary of the key findings of the EGS Assessment.

Section 7 contains key references.

Section 8 provides a glossary of important terms.

Section 9 contains Appendices of other supporting information and the analytical tables used in the EGS assessment.

3.0 Introduction to Ecosystem Goods and Services

This section provides an introduction to what ecosystem goods and services are, and why they are important to maintaining the quality of life in southern Alberta. It is divided into a discussion of the four broad categories of ecosystem services, followed by a description of natural and anthropogenic assets, and finally an explanation of the various sectors of the economy and goods provided.

To provide context to this discussion, Appendix 9-1 shows a list of ecosystem services, natural and anthropogenic assets, and goods in southern Alberta that were considered in the EGS Assessment.

3.1 Ecosystem Services

Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life (Daily, 1997). Ecosystem services are important for the production of economic goods of value to human beings, including crops, fodder, timber and industrial goods. In addition to this benefit to the human economy, ecosystem services are also important for the provision of essential life-support systems and also provide intangible cultural, spiritual, aesthetic and other non-market benefits (Daily, 1997).

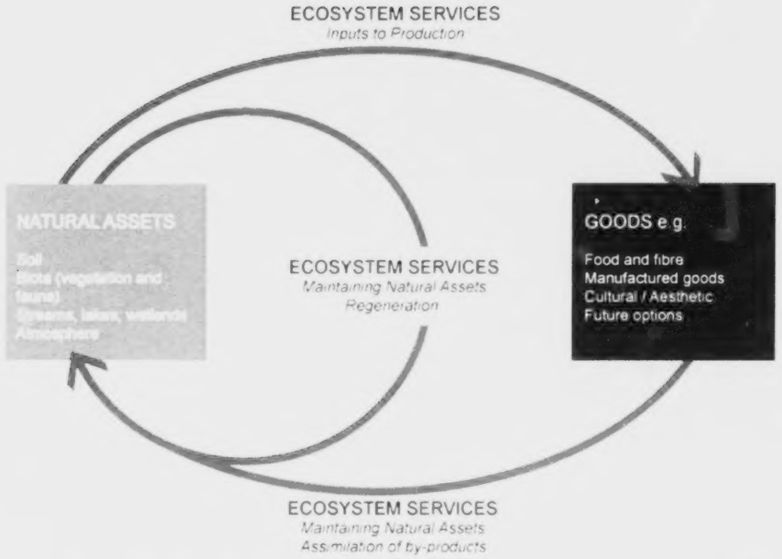
This cyclical relationship between ecosystem services, goods and assets is shown in Figure 3-1 and involves a number of concepts;

- Natural and anthropogenic assets provide goods in southern Alberta through a number of ecosystem services – e.g. the provision of fresh water for drinking, industrial and agricultural purposes;

- Natural assets provide ecosystem services – e.g. native prairie grasslands provide sequestration of carbon as part of gas regulation;

- Ecosystem services also act to maintain natural assets – e.g. the services of soil formation and nutrient cycling are essential for the development and vigour of vegetation communities in native prairie habitats; and,

- Ecosystem services also act to maintain natural and anthropogenic assets through the breakdown of by-products from the production of goods – e.g. the service of waste breakdown and cycling of nutrients from sewage outfalls in southern Alberta rivers helps maintain a healthy aquatic ecosystem.


ECOSYSTEM SERVICES
Inputs to Production
NATURAL ASSETS
Soil
Biota (vegetation and fauna)
Streams, lakes, wetlands
Atmosphere
ECOSYSTEM SERVICES
Maintaining Natural Assets
Regeneration
GOODS e.g.
Food and fibre
Manufactured goods
Cultural / Aesthetic
Future options
ECOSYSTEM SERVICES
Maintaining Natural Assets
Assimilation of by-products

Adapted from Shelton et al. (2002)

Adapted from Shelton et al. (2001)

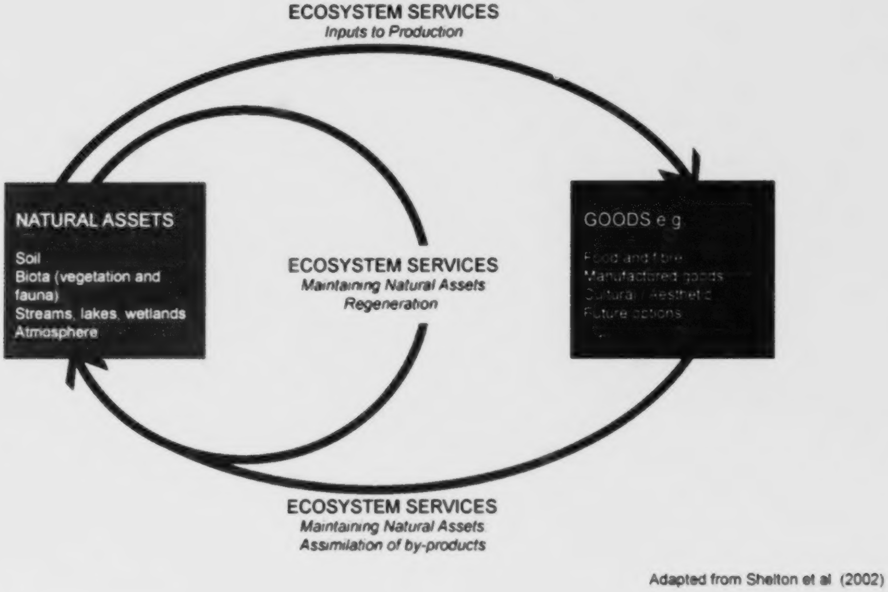
Figure 3-1: Conceptual Framework of the Function of Ecosystem Services

The conceptual framework of the Australian Ecosystem Services Project was used and modified for southern Alberta. The above conceptual framework illustrates the role of ecosystem services in maintaining the condition of natural assets, while also supporting the production of important goods in southern Alberta.

Natural assets are the stock of natural resources (both renewable and non-renewable resources were considered as part of this assessment) from which many goods are produced, while goods are those things produced that are of value to humans in southern Alberta.

Ecosystem services, therefore, contribute to the economic and social well-being of people in and beyond southern Alberta in two ways:

- Through the use of natural resources to provide an input to the production of goods; and


ECOSYSTEM SERVICES
Inputs to Production
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Ecosystem services, therefore, contribute to the economic and social well-being of people in and beyond southern Alberta in two ways:

- Through the use of natural resources to provide an input to the production of goods; and

- By maintaining natural assets via two pathways; first through the regeneration capacities of natural assets and secondly through the assimilation of by-products arising from the production of goods (Ecosystem Services Project, 2003, n.d.)

3.2 Ecosystem Services in Southern Alberta

For the purpose of describing ecosystem services in southern Alberta, we have divided them into four broad categories: regulating services (7), supporting services (5), provisioning services (4) and cultural and aesthetic services (4).

Each service is described in Table 3-1 and in turn below:

- **Regulating services** are the large-scale benefits of life support functions obtained from the regulation of ecosystem processes such as gas regulation, climate and water regulation, disturbance regulation, erosion control and sediment retention, waste treatment and biological control (e.g. pests, predator prey relationships).

- **Supporting services** are essential for the provision of all other services. They are somewhat harder to define as they occur over long time periods, are not readily noticeable, and may not be readily apparent to non-specialists. They include services such as soil formation, primary production, nutrient cycling, pollination and the provision of habitat.

- **Provisioning services** are those products obtained from ecosystems such as water, food, fibre, crops, and genetic resources. Because of the importance of non-renewable resources to the Alberta economy, we include consideration of the production of oil and gas, coal and aggregates in our analysis under the assessment of the service of raw materials.

- **Cultural and aesthetic services** are those non-material benefits that people obtain from nature and ecosystems in southern Alberta. These include aesthetic and cultural benefits, traditional use and spiritual benefits, scientific and educational benefits and recreational benefits.

Table 3-1: List of Ecosystem Services Important to Southern Alberta

Service	Description	Example
Regulating Services		
Gas Regulation	Regulation of the chemical composition of the atmosphere and oceans	CO_2/O_2 balance, ozone for UVB protection
Climate Regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels	GHG regulation, DMS ("sea smell" or ocean gas) production affecting cloud formation
Disturbance Regulation	Dampening of environmental fluctuations and disturbance	Storm protection, flood control, drought recovery
Water Regulation	Role of land cover in regulating runoff and river discharge	Drainage and natural irrigation, medium for transport
Erosion Control and Sediment Retention	Retention of soil within an ecosystem	Prevention of soil loss by wind or runoff; storage of silt in lakes or wetlands; protecting water quality
Waste Treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds	Biodegradation, anaerobic digestion, detoxification, dilution, protection of water quality
Biological Control	Regulation of pest populations and disease	Predator control of prey species, reduction of herbivore by animals
Supporting Services		
Soil Formation	Soil formation process	Weathering of rock and the accumulation of organic material
Primary Production	Production of organic compounds from CO2, principally through the process of photosynthesis	In terrestrial ecosystems, these organisms are mainly plants, in aquatic ecosystems they are algae
Nutrient Cycling	Storage, internal cycling, processing and acquisition of nutrients	Nitrogen fixation, N, P and other elemental or nutrient cycles
Pollination	Movement of floral pollinators	Provisioning of pollinators for the reproduction of plant populations
Habitat/refugia	Habitat for resident and transient populations	Nurseries, habitat for migratory or resident species

Table 3-1 cont'd: List of Ecosystem Services Important to Southern Alberta

Service	Description	Example
Provisioning Services		
Water Supply	Storage and retention of water by watersheds (includes surface and subsurface)	Provisioning, storage and retention of water by watersheds, reservoirs, and aquifers
Food Production	That portion of gross primary production extractable as food	Production of crops, fish, fodder, game, nuts, fruits
Raw Materials	Natural resource production	Production of lumber, fuels, and geological materials (aggregates, minerals)
Genetic Resources	Sources of unique biological materials and products	Medicine, genes for resistance to crop pests, horticultural varieties of plants
Cultural and Aesthetic Services		
Aesthetic	Sensory enjoyment of functioning ecological systems	Artistic, photography, enjoyment
Spiritual and Traditional Use	Spiritual and historic information	Traditional uses for aboriginal and non-aboriginal populations; spiritual sites and religious activities
Science and Education	Use of natural areas for scientific and educational enhancement	Scientific research, science class field trips, increasing public knowledge of natural systems
Recreation	Opportunities for rest, refreshment, and recreation	Eco-tourism, sport fishing, hiking, boating, climbing

Descriptions and examples modified from (Costanza et al., 1997; Ecosystem Services Project, n.d.)

3.2.1 *Regulating Services*

As described above, regulating services are those that provide essential life-support services at a variety of scales ranging from global to microscopic levels.

Gas regulation is the regulation of the chemical composition of the oceans and atmosphere. This involves regulation of the balance between carbon dioxide, nitrogen, oxygen, methane, and other gases, and protection from the sun's damaging rays (UVB) provided by the ozone layer. It also involves the maintenance of good air quality and the transport, dispersion and breakdown of pollutants. In southern Alberta, this service is important for maintaining air quality in urban and rural areas and the regulation of atmospheric gases from agricultural and industrial sources.

Climate regulation refers to the regulation of temperature, precipitation and other climatic processes at both global and local levels. Climate regulation has a close relationship with gas regulation through the regulation of greenhouse gases in the atmosphere, notably carbon dioxide. The importance of local climate in southern Alberta to agricultural production has a significant economic effect.

Disturbance regulation refers to the dampening of environmental disturbances and perturbations that can result in significant loss of human life and economic consequences. This includes the services of flood prevention (regulation by forests and wetlands) and storm protection. Forests on the Eastern Slopes of Alberta are important in controlling spring runoff and minimizing flood damage.

Water regulation refers to the service of regulation of runoff and river discharges and the maintenance of flows across the land surface. In semi-arid landscapes, such as southern Alberta, as much as 65% of rainfall is actually captured, held and released within the landscape. It is this balance between 'blue' and 'green' water that is essential to the maintenance of these assets.

Erosion control and sediment retention refers to the process of minimizing soil loss by wind and runoff processes through the role of the vegetative root matrix and soil biota in soil retention. In southern Alberta, this is important for maintaining the fertility of arable land. The process is also important for controlling the release of sediment to aquatic systems and avoiding increased sedimentation in lakes and rivers.

Waste treatment refers to the recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients or compounds, including waste treatment, pollution control and detoxification. An example in southern Alberta would be the breakdown of excess nutrients from feedlot operations.

Biological control refers to the maintenance of predator prey relationships and control of pests and diseases through species interactions. An example of the importance of this service in southern Alberta is research into the biological control of grasshopper populations as an alternative to chemical pesticides.

3.2.2 *Supporting Services*

Supporting services are those required for the maintenance of other services and natural assets.

Soil formation refers to the process of the weathering of parent rock and the accumulation of organic matter necessary for plant growth. Soil formation is important for the maintenance of native grasslands and those lands under agricultural practices.

Primary production refers to the conversion of sunlight and CO_2 into biomass. In southern Alberta, primary production is essential to the growth of agricultural crops and also the maintenance of healthy grasslands vital for livestock grazing.

Nutrient cycling refers to the storage, internal cycling, processing and acquisition of nutrients through the various biogeochemical cycles (e.g. nitrogen, oxygen, sulphur, phosphorus carbon, and other cycles). In southern Alberta, these "unseen" processes are important for the maintenance of healthy and productive soils and ecosystems.

Pollination refers to the movement of plant genes, or gametes via insects, other animals, wind and water. An example of the importance of this service in southern Alberta is the pollination of hybrid canola seed by bees.

Habitat/refugia refers to habitat and space for both resident and migratory species of plants and animals. This includes important areas of breeding and rearing habitat, and those areas of habitat used in the spring and fall months by migratory species. An example of this service in southern Alberta would be the Canadian Forces Base Suffield National Wildlife Area.

3.2.3 *Provisioning Services*

Provisioning services are those that provide goods of value to human beings. They include the supply of fresh water, the provision of food, fibre, lumber, fuels and fodder and other raw materials and the provision of genetic materials derived from plants and animals. .

Water supply refers to the storage and retention of water by watersheds, reservoirs and aquifers. In southern Alberta, a dependable supply of fresh water is vital for industry (e.g. food manufacturing/processing, oil and gas), agriculture (e.g. irrigation), human consumption (e.g. drinking, bathing, cooking, watering) and power production (Oldman River reservoir). Water is also an important focus of recreational activities in southern Alberta.

Food production refers to the conversion of the sun's energy into edible plants and animals used by humans. This includes fish, game, crops, livestock and subsistence hunting, fishing and gathering. Agriculture is an important contributor to the economy of southern Alberta.

Raw materials refer to that portion of natural resource production that is extractable as raw materials. Because of the importance of the oil and gas industry to the economy of southern Alberta and its' competition for land use with other sectors, it was decided to expand the definition provided by Costanza et al. (1997) to include non-renewable resources in the list of raw materials. Raw materials, within the context of this assessment in southern Alberta, include forest products, oil and gas, coal, minerals and aggregates.

Genetic resources are those sources of unique biological materials and products that have both current and potential future usage. They include medicines, pharmaceuticals, genetic material for pest/pathogen resistance and increased yields, genetic material for animal breeding and other commercial applications.

3.2.4 *Cultural and Aesthetic Services*

In addition to the aforementioned regulating, supporting and provisioning services, there are a suite of other intangible benefits arising from ecosystem services. These include the various cultural and aesthetic services derived from natural and anthropogenic assets. Since these services provide non-market goods, they require valuation using other methods than those typically applied for assessing the value of market-based goods.

Aesthetic services are defined as those that provide sensory enjoyment of functioning ecosystems, such as the provision of scenic views. In southern Alberta, Dinosaur Provincial Park provides scenic views and a unique visual setting amidst the surrounding agricultural and native prairie landscapes.

Spiritual and traditional use services provide spiritual and historic value, incorporating traditional uses of aboriginal and non-aboriginal peoples, and the use and enjoyment of nature or landscapes that provide religious, heritage, cultural and existence value.

Science and education services refer to the use of natural areas for scientific and educational enhancement. Waterton Lakes National Park provides educational and interpretive programs to visitors and serves as a scientific benchmark for research into natural processes and human derived change.

Recreation services are those that provide opportunities for rest, refreshment and recreation. These services provide non-market recreational benefits and include activities such as eco-tourism, bird and nature watching, hiking, boating, climbing and sports fishing. A wide variety of recreational benefits are provided by lakes in southern Alberta, such as Kinbrook Island and Beauvais Lake Provincial Parks.

3.2.5 *Interrelationships Between Ecosystem Services*

Many ecosystem services are not stand-alone services but are in fact intrinsically related with one or a suite of other services. Table 3-2 shows how these 20 ecosystem services are directly interrelated to each other, or not directly related or dependent upon each other.

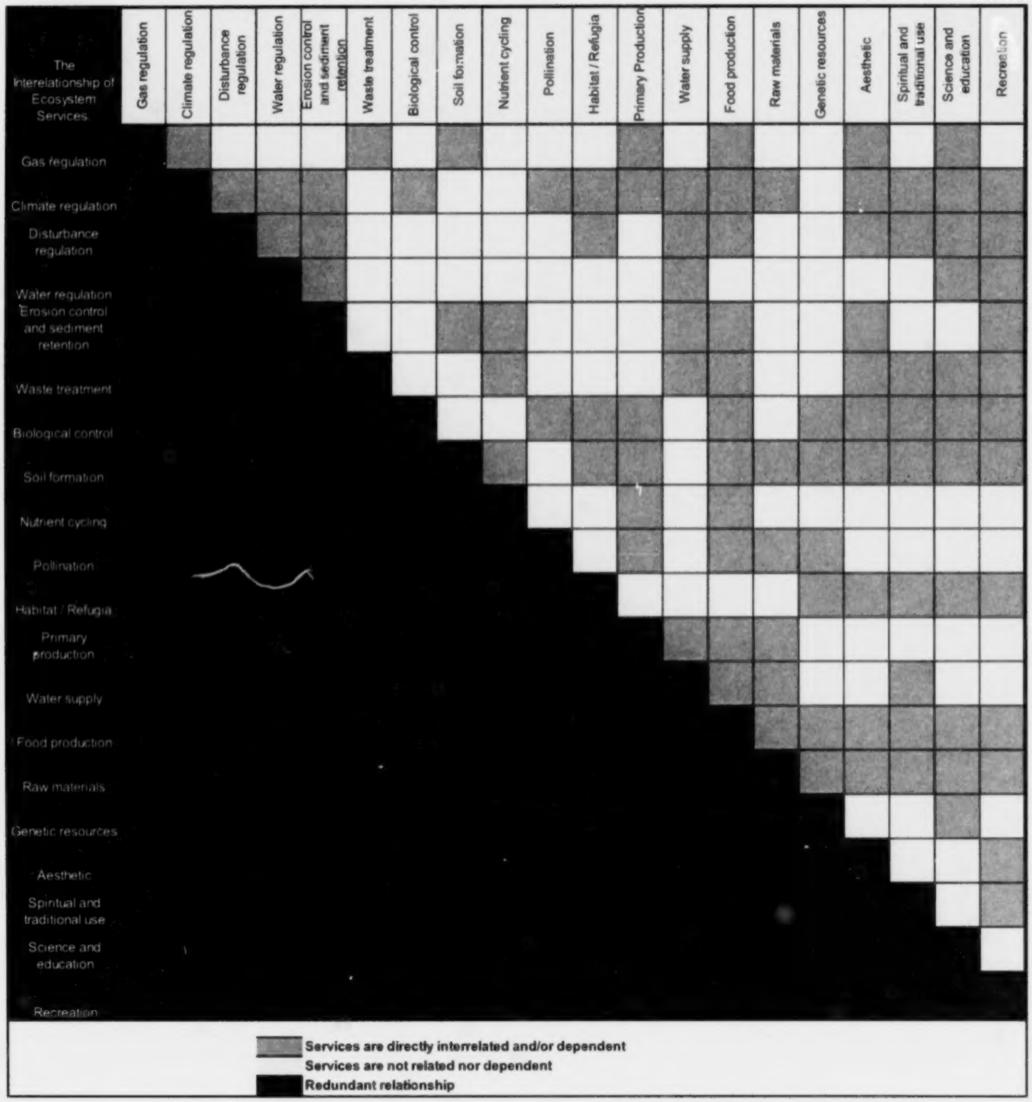
For example, the service of climate regulation is related to and affects or is affected by the services of gas regulation, disturbance regulation, water regulation, erosion and sediment retention, pollination, habitat/refugia, primary productions, water supply, food production, raw materials and all four cultural/aesthetic services.

Table 3-2: Interrelationships Between Ecosystem Services

The Interrelationship of Ecosystem Services.	Gas regulation	Climate regulation	Disturbance regulation	Water regulation	Erosion control and sediment retention	Waste treatment	Biological control	Soil formation	Nutrient cycling	Pollination	Habitat Refugia	Primary Production	Water supply	Food production	Raw materials	Genetic resources	Aesthetic	Spiritual and traditional use	Science and education	Recreation
Gas regulation	■																			
Climate regulation	■	■																		
Disturbance regulation	■	■	■																	
Water regulation	■	■	■	■																
Erosion control and sediment retention	■	■	■	■	■															
Waste treatment	■	■	■	■	■	■														
Biological control	■	■	■	■	■	■	■													
Soil formation	■	■	■	■	■	■	■	■												
Nutrient cycling	■	■	■	■	■	■	■	■	■											
Pollination	■	■	■	■	■	■	■	■	■	■										
Habitat / Refugia	■	■	■	■	■	■	■	■	■	■	■									
Primary production	■	■	■	■	■	■	■	■	■	■	■	■								
Water supply	■	■	■	■	■	■	■	■	■	■	■	■	■							
Food production	■	■	■	■	■	■	■	■	■	■	■	■	■	■						
Raw materials	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
Genetic resources	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
Aesthetic	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
Spiritual and traditional use	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Science and education	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Recreation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

□ Services are directly interrelated and or dependent
□ Services are not related nor dependent
■ Redundant relationship

Table 3-2: Interrelationships Between Ecosystem Services



The Interrelationship of Ecosystem Services	Gas regulation	Climate regulation	Disturbance regulation	Water regulation	Erosion control and sediment retention	Waste treatment	Biological control	Soil formation	Nutrient cycling	Pollination	Habitat / Refugia	Primary Production	Water supply	Food production	Raw materials	Genetic resources	Aesthetic	Spiritual and traditional use	Science and education	Recreation
Gas regulation	■	▨	□	□	□	▨	□	▨	□	□	□	▨	□	▨	□	□	▨	□	▨	□
Climate regulation	■	■	▨	▨	▨	□	▨	□	□	▨	▨	▨	▨	▨	▨	□	▨	▨	▨	▨
Disturbance regulation	■	■	■	▨	▨	□	□	□	□	□	▨	□	▨	▨	□	□	▨	▨	▨	▨
Water regulation	■	■	■	■	▨	□	□	□	□	□	□	□	▨	□	□	□	□	□	▨	▨
Erosion control and sediment retention	■	■	■	■	■	□	□	▨	▨	□	□	□	▨	▨	□	□	▨	□	□	▨
Waste treatment	■	■	■	■	■	■	□	□	▨	□	□	□	▨	▨	□	□	▨	▨	▨	▨
Biological control	■	■	■	■	■	■	■	□	□	▨	▨	▨	□	▨	□	▨	▨	▨	▨	▨
Soil formation	■	■	■	■	■	■	■	■	▨	□	▨	▨	□	▨	▨	▨	▨	▨	▨	▨
Nutrient cycling	■	■	■	■	■	■	■	■	■	□	□	▨	□	▨	□	□	□	□	□	□
Pollination	■	■	■	■	■	■	■	■	■	■	□	▨	□	▨	▨	▨	□	□	□	□
Habitat / Refugia	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	▨	▨	▨	▨	▨
Primary production	■	■	■	■	■	■	■	■	■	■	■	■	▨	▨	▨	□	□	□	□	□
Water supply	■	■	■	■	■	■	■	■	■	■	■	■	■	▨	▨	□	□	▨	□	□
Food production	■	■	■	■	■	■	■	■	■	■	■	■	■	■	▨	▨	▨	▨	▨	▨
Raw materials	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	▨	▨	▨	▨	▨
Genetic resources	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	▨	□
Aesthetic	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	▨
Spiritual and traditional use	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	▨
Science and education	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□
Recreation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

▨ **Services are directly interrelated and/or dependent**
□ **Services are not related nor dependent**
■ **Redundant relationship**

Indirect relationships between services are not shown. For example, a reduction in water supply may lead directly to a reduction in primary productivity (assuming water was a limiting factor for plant growth). Where two services are shown to be not related, there is often an indirect relationship (typically involving a 3rd service) between the services. For example, a relationship between soil formation and pollination is not indicated. However, if one considers a third service, primary production, an indirect relationship is revealed. Primary production often relies on pollination for the successful propagation of plant species, and soil formation, in part, relies on primary production for a source of organic matter. Therefore, soil formation indirectly relies on pollination through primary production. If the service of pollination was impacted, it appears likely that soil formation would also be impacted.

It is likely that if all direct and indirect relationships between various services were considered, that each service would be interdependent in some way with all other services. This will, however, not be the case in all situations. Relationships between services are not consistent between different ecosystems and an understanding of the specific traits of the species that make up each ecosystem is necessary (Havstad et al. 2007). This type of analysis may be a beneficial next step in this research, although the goals of the analysis (what research question is to be answered) should be considered carefully.

This analysis and other similar research have created conceptual divisions within the actual network of ecosystem functions by creating the concept of ecosystem services. This is done to facilitate human understanding and analysis. While this is a necessary step to begin to integrate the concept of EGS into our society, it can also lead to problems. The array of functions provided by nature is not inherently amenable to division and classification. One example is the division of water related functions into the ecosystem services called water regulation and water supply. In some cases the separation of the regulating service (water regulation) and the provisioning service (water supply) makes sense. This is useful where there is a need to focus on the benefits to humans (provisioning) versus the ecosystem function irrespective of human use (regulating). However, on a functional level, these services are very hard to separate. Havstad et al. (2007) stress that topography, soil, and vegetation properties (all related to the function of water regulation) directly impact the amount of water available to groundwater recharge (in many cases impacting the provisioning and supply of water to humans). Thus when looking past the conceptual divisions of ecosystem function the deeply interconnected nature of ecosystem services becomes evident. If one service is impacted, it becomes a complex but critical task to assess which other services may be impacted or lost. More work is needed to define the extent and dependency of these relationships in southern Alberta.

3.3 Assets in Southern Alberta

An asset is defined as something valuable or useful. The Ecosystem Goods and Services Assessment considers a wide range of natural and anthropogenic assets across southern Alberta. The list of assets was derived from Alberta Environment's spatial database. The intent of dividing these assets into natural and anthropogenic origins was to allow for future spatial modelling of asset value and consequences of changing the distribution of assets across the southern Alberta landscape.

3.3.1 *Natural Assets*

Natural assets refer to the stock of natural resources from which many goods are produced in southern Alberta. For the purposes of the EGS Assessment, they have been categorized into native prairie, forest, aquatic, and geological assets (see Tables 3-3 to 3-8). A description of each asset in these categories is provided in the tables that follow.

Table 3-3: Description of Natural Assets – Native Prairie

Native Prairie Asset	Description	Example
Needle and Thread Dry Mixed Grass	This plant community is located on nearly level slopes that are moderate to well-drained. The range sites are generally loamy and soils are Orthic and Solonetzic Brown.	Western porcupine grass, needle and thread grass, western wheat grass, blue grama grass, June grass, plains wheat grass, pasture sagewort and silver sagebrush, ringed sage, thread-leaved sedge.
Northern Wheat Dry Mixed Grass	This plant community refers to plants found within the Cypress and Milk River Uplands of southern Alberta. The range sites are generally loamy and the soils are Orthic Dark Brown, Rego Dark Brown and Dark Brown Solodized Solonetz. Drainage is moderate to well-drained.	Needle and thread grass, June grass, northern wheatgrass, western wheatgrass, Idaho fescue, Kentucky bluegrass, snowberry, silver sagebrush, and sandberg bluegrass.
Needle and Thread Sand Grass – Dry Mixed Grass	This plant community is characterized by clayey soils that are moderate to well-drained. The slope ranges from very gentle to gentle and the aspect is southerly. The soils are Orthic Regosolic and Orthic Brown.	Pasture sagewort, prickly pear cactus, western wheatgrass, sandberg bluegrass, blue grama grass, June grass, green needle grass, needle and thread-sandgrass, chokecherry, sedge - sandgrass and foxtail barley.

Table 3-3 cont'd: Description of Natural Assets – Native Prairie

Native Prairie Asset	Description	Example
Mixed Grass	This plant community occurs east of the foothills within the grasslands natural region, and is characterized by moister soils than found in the dry mixed grass areas. It has undulating plain, with some rolling to hummocky areas and dark brown chernozem soils.	Rough fescue, porcupine grass, June grass, sand grass, western wheatgrass; silver sagebrush, needle and thread grass, northern wheatgrass, 5-seed grass, Idaho fescue, sand reed grass, and salt grass.
Fescue Grasslands	The Fescue Grasslands are located on moderate to strong slopes that are well-drained to rapidly drained. The range sites are variable, ranging from thin breaks to steep slopes to gravel and shallow gravel. The dominant soil types are Black Chernozem and Orthic Dark Brown.	Western wheatgrass, rough fescue, parry's oat grass, needle and thread grass, silver sagebrush, June grass, western porcupine grass, bluebunch fescue, sedge, little bluestem, green needle grass, upland sedge, salt grass, and Idaho fescue.
Rocky Mountain and Parkland Fescue	The Parkland Fescue plant community forms a narrow transition band between the Foothills Fescue subregion and the Montane Subregion. Predominant soils are Black and Dark Brown Chernozems. Drainage is moderate to well-drained and the slope is variable.	Willow, rough fescue, parry's oatgrass, sandgrass, bearberry and Idaho fescue.
Prairie Treed and Riparian Cottonwood	The Prairie Treed and Riparian Cottonwood plant community occurs on older alluvial bars of major streams and rivers. Soils are typically Regosols and range sites vary from silt loam to silty clay. Soils are generally poorly drained with high available water early in growing season.	Narrow-leafed cottonwood, green ash, saskatoon, western clematis, choke cherry, poison ivy, skunkbrush, golden currant, reed canary grass, bluegrass, slender wheatgrass, perennial ragweed, Indian hemp, prairie sagewort and showy milkweed.
Prairie Shrub	The Prairie Shrub community has very diverse attributes. Range sites vary from loamy to blowout, and the soils are Solonetzic Brown, Cumulic Regosol and Orthic Black. Drainage is well-drained to rapidly drained and the slope ranges from gentle to steep.	Silver sagebrush, western porcupine grass, needle and thread grass, snowberry, green needle grass, juniper, sand grass, rough fescue, bluebunch fescue and western wheatgrass.
Badlands and Thin breaks	The Badlands are defined as nearly barren or barren lands, with exposure to softrock, hardrock, or surficial geology. Thin breaks are areas with a veneer (<1 meter or less) of parent material overlaying softrock or bedrock. Bedrock will be at or near the soil surface.	Northern wheatgrass, June grass, sedge, thread-leaved sedge and moss phlox.

Table 3-4: Description of Natural Assets – Forest

Forest Asset	Description	Examples
Forest Shrub	Includes areas of forest that are open or closed shrub meadows, pastures, or shrubby wetlands.	Common wild rose, thorny buffaloberry, Red-Osier dogwood.
Hardwood Forest	Forest stands that are predominately deciduous (greater than 80% of the stand).	Trembling aspen, balsam poplar.
Mixed Wood Forest	The Mixedwood plant community is characterized by low relief and level to undulating terrain. Soils are typically Gray luvisols in well-drained, upland till sites and Eutric brunisols in coarse-textured sandy uplands.	Aspen poplar, balsam poplar, white spruce and balsam fir.
Spruce and Fir Forest	Forest stands that are pure conifer types having white spruce, Engelmann spruce, black spruce or a balsam fir or Douglas fir as more than 30% of the stand, black spruce is also included but represents a very small amount. Forest riparian is also included in this category.	White spruce, Engelmann spruce, alpine fir or alpine larch, lodgepole pine and Douglas fir.
Pine Forest	Pure conifer forest stand with lodge pole pine as the leading species within the stand.	Lodgepole pine, jack pine, limber pine.

Table 3-5: Description of Natural Assets – Aquatic

Aquatic Asset	Description	Examples
Lentic (Standing)	Lentic water bodies are basins that lack a defined channel and floodplain. They can be permanent or intermittent bodies of water.	Lakes, reservoirs, potholes, marshes, ponds and stockponds.
Lotic (Flowing)	Lotic water bodies are running water systems such as rivers, streams, and drainage ways. The channel is an open conduit, which periodically or continuously, carries flowing water.	Perennial streams, intermittent channels, ditches, etc.
Wetlands **Forest and Prairie**	Wetlands are areas that under normal circumstances have hydrophytic vegetation, hydric soils and wetland hydrology. The analysis of assets considered forest and prairie wetlands separately to remain consistent with Alberta Environment's land cover types.	Bogs, fens, marshes, sloughs, wet meadows and riparian zones.

Table 3-6: Description of Natural Assets – Geologic

Geologic	Description	Example
Bare Soil and Rock	Areas of exposed rock and soil related specifically to the non grasslands areas of the regions. Includes exposed mountain tops, scree slopes and stream valley bottoms that are without vegetation.	Mountain tops; scree slopes.
Ice	Areas of permanent ice related to glaciers only.	Glaciers.

3.3.2 *Anthropogenic Assets*

Anthropogenic assets are defined as man-made assets, the footprint of which now occupies areas of former natural assets. For the purposes of this assessment, they have been divided into agricultural and other anthropogenic assets. Agricultural assets are further subdivided into "Irrigated" and "Dryland" assets which largely depend on their geographic distribution in southern Alberta. While there may be exceptions to the crops associated with irrigated and dryland agriculture, these categories generally hold true.

Table 3-7: Description of Anthropogenic Assets – Agricultural

Agricultural Assets	Description	Examples
Irrigated		
Cereal Crops	Cereal crops are mostly grasses cultivated for their edible grains or seeds.	Barley, buckwheat, canary seed, grain corn, oats, proso millet, rye and wheat.
Oilseeds and Legumes	Legumes are important rotational crops as they fix nitrogen and produce nutritionally valuable seeds for human and animal consumption.	Canola, flax, hyola, mustard, safflower, sunflower, chickpeas, dry beans, dry peas and lentils.
Specialty Crops	These crops are gaining in popularity because of high value, improved plant breeding, machine development and better processing and marketing options.	Alfalfa seed, catnip, mint, onions, soybeans, sugar beets, sweet corn, timothy, turf sod and potatoes.
Forage Crops	Forage crops include those crops meant for beef, horse or pig feed.	Alfalfa, oats silage, silage corn, sweet clover, milk-vetch and white clover.
Dryland		
Cereal Crops	Cereal crops are mostly grasses cultivated for their edible grains or seeds.	Barley, buckwheat, canary seed, grain corn, oats, proso millet, rye and wheat.
Oilseeds and Legumes	Legumes are important rotational crops as they fix nitrogen and produce nutritionally valuable seeds for human and animal consumption.	Canola, flax, hyola, mustard, safflower, sunflower, chickpeas, dry beans, dry peas and lentils.
Forage Crops	Forage crops include those crops meant for beef, horse or pig feed.	Alfalfa, oats silage, silage corn, sweet clover, milk-vetch and white clover.
Tame Pasture	Pasture includes both cut and perennial crops including corn, wheatgrass, hay, fescue and others. In some cases this is an estimated value rather than an inventory.	Altai wild rye, bird's-foot trefoil, Bromegrass, cicer milk-vetch, creeping red fescue, crested wheatgrass, crown vetch, intermediate wheatgrass, meadow bromegrass, meadow fescue, native pasture, orchard grass, pubescent wheatgrass, reed canarygrass, smooth bromegrass and tall fescue.

Table 3-8: Description of Anthropogenic Assets – Other

Other Anthropogenic Assets	Description	Example
Roads and Rails	All major and minor roads which would at some point be used by either light or heavy duty vehicles, for all uses including industrial and recreational and are considered permanent landscape features that exist outside of urban areas (which would be considered urban). All active or non-active existing railways on the landscape.	Highways, township gravel roads, forestry roads, oil and gas, recreational roads, facilities access and railroads.
Rural/Ag Residential	Residential home sites specifically associated with agricultural areas.	House and surrounding outbuildings and 'yard' area.
Cities and Towns	All urban areas in which the entire area is counted as a 'mixed use' zone made up of roads, houses, parks, schools, businesses, etc.	Cities, towns, villages, summer villages including all landuses within as a total 'area'
Well Sites	The area of each active or inactive wellsite, which has not been reclaimed. The areas are based on an average well site size.	Active oil well.
Pipelines, Transmission and Seismic Lines	Area of disturbance created by installing pipelines, or performing seismic activity. Only large transmission lines that are not associated with roadways are included.	Pipeline (occurring on native prairie), seismic (located in forested areas) and transmission lines.
Power Generation	Power generation in southern Alberta is considered to be representative of the Alberta mix with both renewable and non-renewable sources. In Alberta the mix is approximately 88% from coal and natural gas combustion with the remaining 12 per cent from an array of sources including wind and hydroelectric. Only power sources currently in place are considered in this assessment.	Includes coal-fired, hydroelectric and wind power generation.
Feedlots	All feedlots are based on an average size as calculated using statistical information when inventory information was absent.	Confined feeding operations, Beef finishing lots.

Table 3-8 cont'd: Description of Anthropogenic Assets – Other

Other Anthropogenic Assets	Description	Example
Recreation – Campgrounds and Ski Hills	Service areas of recreation including campgrounds, ski hills, golf courses and day use areas. These don't include areas, which fall within urban areas, it also doesn't include walking or hiking trails or areas defined as recreation areas which have no services.	Ski hills, campgrounds, golf courses, recreation areas falling outside of cities and town boundaries
Mines and Pits	Gravel pits are based on an average size and a statistical calculation within the grassland area, and actual inventory within the forest area, all coalmines are direct interpretations of actual areas.	Coalmines, limestone quarries, gravel pits and burrow pits, surface mines and open pits.
Industrial Sites	All industrial plants and processing facilities that do not fall within urban areas, based on an average size calculation.	Food processing plants, gas plants, forestry processing plants, general processing or production plants, and wind mills.
Reservoirs	Man-made Lentic water bodies.	All man-made reservoirs.
Canals	Man-made major canals, aqueducts and ditches.	All man-made canals.

3.4 Goods in Southern Alberta

For the purposes of this assessment, goods are defined as all things produced in southern Alberta that are of value to humans. Similar to the Australian Ecosystem Services Project, this project has largely emphasized the role of natural assets in the production of goods, although the role of manufactured capital, technology, labour and social institutions are also notable inputs to the production of goods (Ecosystem Services Project, n.d.). Many of the goods produced in southern Alberta are well documented and immediately come to mind, given our economic dependence on them for consumption or export. Examples include goods such as beef and other livestock, grains and other crops, and oil and gas. The scope of goods considered in this assessment however is much broader than these easily quantifiable tangible goods. Intangible goods such as recreational opportunities and aesthetic, spiritual and existence values are also goods produced by natural and man-made assets in southern Alberta, although their economic value is often largely discounted or wholly disregarded by neoclassical economics.

While the specific goods produced in a landscape differ depending upon the type of natural asset, the economic sectors have been categorized under the Standard Industrial Classification (SIC) system. The SIC is based upon the Fisher-Clark Model named after the individuals who first subdivided the economy into three categories or sectors (primary, secondary, tertiary) in the 1930s (Clark, 1940; Fisher, 1939). The model is still relevant today and is used in both mainstream economics and national accounts, such as Statistics Canada, although with some variations and additions within the sectors. The industries in each of these sectors are also well known.

The EGS Assessment uses the Standard Industrial Classification system of primary, secondary and tertiary sectors. It also incorporates aspects of the *Socio-economic Aspects* study prepared for Alberta Environment (Global Training Inc., 2004). The Socio-economic Aspects Study prefers instead to use primary, manufacturing, and service categories to describe the sectors of the southern Alberta economy. A twelve-sector aggregation provided in the Socio-economic Aspects study was adopted with a few minor modifications.

In addition to the aforementioned primary, secondary and tertiary sectors, the EGS Assessment also considered intangible goods which have value, but are not represented in the SIC or the Socio-economic Aspects study. Cultural, spiritual and aesthetic goods include those “goods” not represented in economic accounts such as Gross Domestic Product (GDP). Unlike the goods in the primary, secondary, and tertiary sectors, cultural and aesthetic goods are somewhat less obvious and more difficult to value, compared to tangible goods.

The following provides a description of each sector and a listing of the industries that have been organized into each sector (see Appendix 9-1). Furthermore, while the sectors and the industries are not goods in and of themselves, they do lead to the production of goods. Therefore, the term “goods” is used interchangeably with the industry that produces the good.

3.4.1 *Primary Sector of Industry*

The primary sector involves the conversion of natural resources into primary products. Most products from this sector are considered as raw materials for other industries. The following six categories of primary goods were considered in southern Alberta:

- **Agriculture – Crop / Vegetable** – refers to those commercially produced crops arising from both irrigated and non-irrigated lands;
- **Agriculture – Livestock** – a wide array of livestock are currently being produced in southern Alberta by farmers and ranchers. Beef, bison, elk, goats, poultry, pork, and sheep are typically being raised in either a confined (feedlot) or non-confined (range/grazing) setting;
- **Oil and Gas** – refers to the naturally occurring non-renewable hydrocarbon compounds in liquid or gaseous states that are trapped in underground rock or reservoirs, and are the largest single source of resource development revenue in Alberta;
- **Forestry and Forest Products** - a renewable natural resource that provides the raw materials of lumber and pulp that can be transformed into a wide array of useable products;
- **Mining (aggregates, coal)** – surface or underground mining of the earth’s crust produces naturally occurring coal and metallic and non-metallic minerals; and,
- **Subsistence – hunting, fishing, trapping, gathering, other** – while often associated with traditional hunter-gatherer societies, subsistence is used in the

southern Alberta context to represent a number of practices which result in food provision through non-commercial means.

Several modifications were made to derive the list of primary goods. Given its overall importance to southern Alberta, and in consideration of differing inputs and impacts, agriculture was divided into Agriculture – Crop/Vegetable and Agriculture – Livestock. Further, the production of agricultural goods was distinguished from the processing of agricultural products into goods (the latter was considered a secondary good).

Oil and gas is a good that does not show up in the Socio-economic Aspects Study, but rather is considered to be part of the mining sector. Given the significance of this industry to southern Alberta, and the goods that depend upon its production, in addition to the specialized nature of this activity, oil and gas was analyzed independent of other mining activities.

The Socio-economic Aspects Study (p. 16) chose to aggregate fishing and mining as a single sector. Because these goods produced are too dissimilar to allow aggregation for these purposes, the EGS Assessment considered them as separate goods. The activities of hunting and fishing were aggregated with fishing and trapping to create the good which is referred to as "subsistence", in order to capture the traditional hunter/gatherer lifestyle.

3.4.2 *Secondary Sector of Industry*

The secondary sector, which is also referred to interchangeably as the manufacturing sector, includes those economic sectors that create a finished, usable product such as manufacturing and construction. This sector of industry generally takes the output of the primary sector and manufactures finished goods or products to a point where they are suitable for use by other businesses, for export, or sale to domestic consumers. Within the secondary sector of industry, the following three categories of goods produced in southern Alberta were identified:

- **Agriculture – Processing** – the primary production of both crop and livestock agriculture products creates a substantial opportunity to transform these outputs into intermediate or finished goods (e.g. potatoes to French fries, or livestock to steaks);
- **Oil and Gas – Refining** – this industrial process transforms crude oil into more useful petroleum products, such as gasoline, diesel fuel, asphalt base, heating oil, kerosene, and natural gas into liquefied petroleum gas for transport; and,
- **Other Manufacturing** – refers to all secondary production which is not covered by agriculture or oil and gas refining such as the milling of lumber into wood products, etc.

As noted above, agriculture production and agricultural processing are split among the primary and secondary sectors.

3.4.3 *Tertiary Sector of Industry*

The tertiary sector, or alternatively service sector, is one of the three main industrial categories of a developed economy. According to some economists, the service tends to be wealth consuming, whereas manufacturing is wealth producing. The tertiary sector of industry involves the provision of services to businesses as well as final consumers. Within the tertiary sector, the following seven goods produced in southern Alberta were identified:

- **Construction** – refers to the building or assembly of any infrastructure on a site or sites and includes all sub-trades that are required to successfully undertake a given project;
- **Transportation and utilities** – includes the transportation and storage of all goods, in addition to utilities such as water, sewer, electricity and communications;
- **Trade (wholesale/retail)** – comprises both wholesaling and retailing merchandise and also rendering services incidental to the sale of merchandise that represents the final step in the distribution of merchandise;
- **Health and education** – are goods under the jurisdiction of the provincial government of Alberta and comprises pre-school, primary, secondary, post-secondary and vocational education and all facets of the formal and informal health care systems;
- **Tourist services** - encompass travel for predominantly recreational or leisure purposes, and involves a number of tangible and intangible elements;
- **Government (the public sector) and non-profit** –pertains to the administration of government services and delivery of goods by and for the government, whether national, provincial or municipal. The downloading of services by government has led, in some cases, to the emergence of the non-profit sector to act in this capacity; and,
- **Other services** – this category allows for the categorization of niche services that do not logically fit within any of the preceding categories.

The seven tertiary sectors used to analyze the importance of ecosystem services in southern Alberta are the same as the aggregated sectors developed by Global Training for the Socio-economic Aspects Study (p. 16).

3.4.4 *Cultural and Aesthetic Goods*

Cultural and aesthetic goods considered in the EGS Assessment included the following five categories:

- **Biodiversity** is defined as the variety of life in all its forms, levels and combinations, including ecosystem diversity, species diversity and genetic diversity (IUCN, UNEP, & WWF, 1991). A high or higher level of biodiversity relative to native conditions is a normative goal for ecosystem management. It should also be noted that biodiversity is highly interdependent with all other cultural and aesthetic goods;
- **Aesthetics** is a branch of philosophy dealing with the nature of beauty, art, and taste and with the creation and appreciation of beauty. Aesthetic goods are those goods produced in the landscape that provide sensory pleasures, such as scenic views;

- **Cultural goods** are goods found in the landscape that have cultural significance. While traditional uses of First Nations are a significant component of this "good", cultural goods refers to all cultures existing in the landscape (European, Asian, Latin, etc.);

- **Future options** refer to opportunities that could arise in the future, but for whatever reason, humans have yet to recognize their value. An example of a future option may be a plant growing in southern Alberta that has healing properties that have yet to be identified; and,

- **Non-market recreational opportunities** are similar to tourist services; however, unlike tourist services, non-market recreational opportunities have no direct monetary value attached to them. They include activities such as hiking, bird watching, cross-country skiing, etc.

3.5 Conceptual Linkages Among Ecosystem Services, Assets and Goods

In order to begin to understand the relationships between assets, ecosystem services and goods and to help formulate the analytical Excel tables needed for the EGS Assessment, a conceptual model of linkages was developed. The conceptual model examines the linkages (strong, moderate or weak) between groups of assets (native prairie, forest, agricultural, aquatic, geologic and other anthropogenic), ecosystem services (regulating, supporting, provisioning and cultural) and goods (primary, secondary, tertiary and cultural/aesthetic). To assist in the formulation of the model, an analysis of the relationship between assets and ecosystem services was completed, the results of which are shown in Figure 3-2 and Appendix 9-2. The conceptual model also was used in the determination of the importance of ecosystem services in southern Alberta as shown in Appendices 9-7 to 9-26.

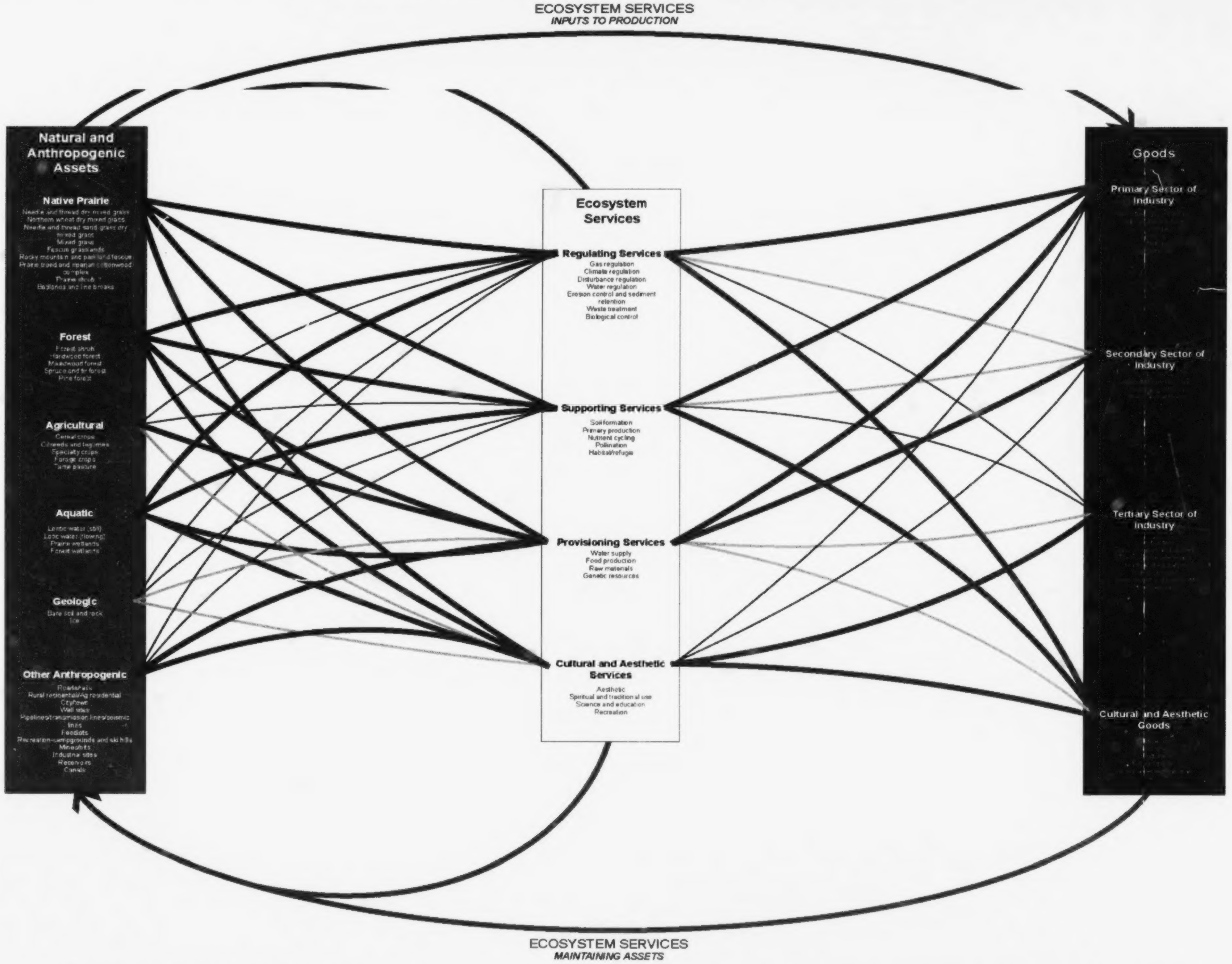
A number of assumptions helped guide the development of the conceptual model as follows:

- Assets (both natural and anthropogenic) provide services which are important to the production of goods, or the maintenance of the asset (more relevant in the case of natural assets);

- There is no overall directionality expressed in the linkages – in some cases this may be unidirectional, in other cases bi-directional. The lack of supporting data and coarseness of the analysis (e.g. groups of services, assets and goods) only allowed for the establishment of linkages without assessment of directionality. This could be considered at a later date; and,

- Because assets, services and goods are considered as groups of assets, no conclusions could be drawn with respect to specific assets, services and goods. These have been evaluated using the Excel spreadsheet tables that follow.

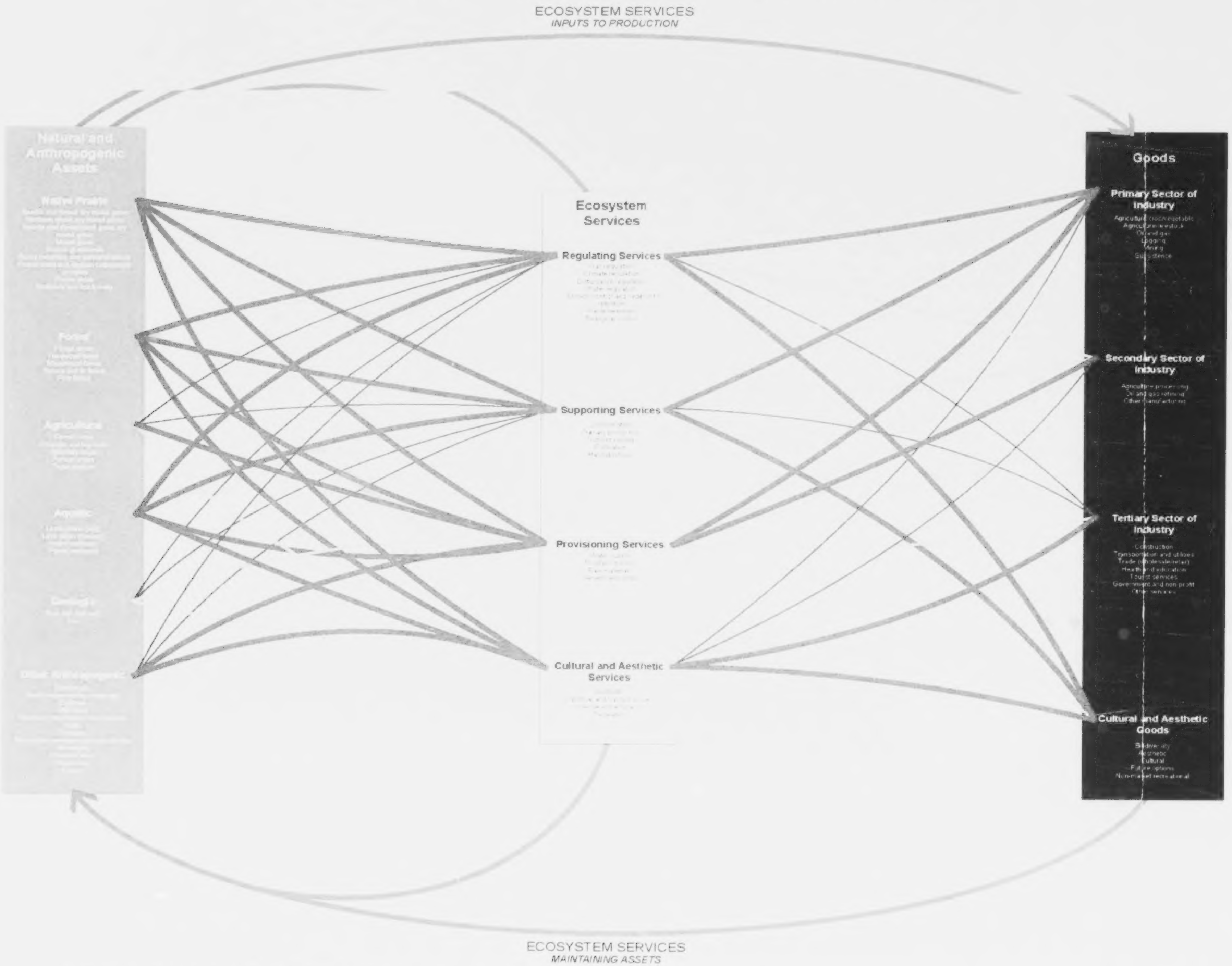
Figure 3-2: Conceptual Linkages among Assets, Ecosystem Services and Goods


ECOSYSTEM SERVICES
INPUTS TO PRODUCTION
Natural and Anthropogenic Assets
Native Prairie
Needle and thread dry mixed grass
Northern wheat dry mixed grass
Needle and thread sand grass dry mixed grass
Mixed grass
Fescue grasslands
Rocky mountain and parkland fescue
Prairie treed and riparian cottonwood complex
Prairie shrub
Badlands and line breaks
Forest
Forest shrub
Hardwood forest
Mixedwood forest
Spruce and fir forest
Pine forest
Agricultural
Cereal crops
Oilseeds and legumes
Specialty crops
Forage crops
Tame pasture
Aquatic
Lentic water (still)
Lotic water (flowing)
Prairie wetlands
Forest wetlands
Geologic
Bare soil and rock
Ice
Other Anthropogenic
Roads/rails
Rural residential/Ag residential
City/town
Well sites
Pipelines/transmission lines/seismic lines
Feedlots
Recreation-campgrounds and ski hills
Mines/pits
Industrial sites
Reservoirs
Canals
Ecosystem Services
Regulating Services
Gas regulation
Climate regulation
Disturbance regulation
Water regulation
Erosion control and sediment retention
Waste treatment
Biological control
Supporting Services
Soil formation
Primary production
Nutrient cycling
Pollination
Habitat/refuge
Provisioning Services
Water supply
Food production
Raw materials
Genetic resources
Cultural and Aesthetic Services
Aesthetic
Spiritual and traditional use
Science and education
Recreation
Goods
Primary Sector of Industry
Secondary Sector of Industry
Tertiary Sector of Industry
Cultural and Aesthetic Goods
ECOSYSTEM SERVICES
MAINTAINING ASSETS

This figure shows the strength of the linkages between assets, ecosystem services and goods. No directionality is indicated. See the text that follows for a detailed explanation of these relationships.

▬ Strong Link ▬ Moderate Link ▬ Weak Link

Figure 3-2: Conceptual Linkages among Assets, Ecosystem Services and Goods


ECOSYSTEM SERVICES
INPUTS TO PRODUCTION
Natural and Anthropogenic Assets
Native Prairie
Forest
Agriculture
Aquatic
Other Anthropogenic
Ecosystem Services
Regulating Services
Supporting Services
Provisioning Services
Cultural and Aesthetic Services
Goods
Primary Sector of Industry
Agriculture crop/vegetable
Agriculture livestock
Oil and gas
Logging
Mining
Subsistence
Secondary Sector of Industry
Agriculture processing
Oil and gas refining
Other manufacturing
Tertiary Sector of Industry
Construction
Transportation and utilities
Trade (wholesale/retail)
Health and education
Tourist services
Government and non profit
Other services
Cultural and Aesthetic Goods
Biodiversity
Aesthetic
Cultural
Future options
Non-market recreational
ECOSYSTEM SERVICES
MAINTAINING ASSETS

This figure shows the strength of the linkages between assets, ecosystem services and goods. No directionality is indicated. See the text that follows for a detailed explanation of these relationships.

Strong Link Moderate Link Weak Link

3.5.1 *Linkages Between Assets and Services*

As part of formulation of the conceptual model to describe the linkages between ecosystem services, goods and assets in southern Alberta, a cross-tab analysis between ecosystem services and assets was undertaken to assess the strength of their relationship (see Appendix 9-2).

- Positive – there is a highly positive relationship between the asset and the service;
- Somewhat positive – the relationship between the asset and the service while positive, is not as strong;
- Neutral – there is neither a positive or negative relationship or effect between assets and services;
- Somewhat negative – the asset may impact the service in a slightly negative manner; and,
- Negative – the asset may have a highly negative relationship or effect on the provision of a service.

The results of this analysis are shown in Appendix 9-2 and described below:

- Not surprisingly there is a positive relationship between the existence of natural assets (both terrestrial and aquatic) and the provision of ecosystem services;
- Conversely there is a negative relationship between anthropogenic assets and the provision of ecosystem services, in that human activities can impact on ecosystem services, yet this effect is not normally considered in economic accounts;
- Cities and towns, mines and industrial sites have the greatest negative effect on ecosystem services. Cities and towns however have a very positive relationship with science/education and recreation; and,
- There is a somewhat negative relationship between agricultural assets and ecosystem services. This relationship shows the importance of ecosystem services to the production of agricultural goods, while at the same time agricultural production can impact ecosystem services or rely on man-made goods as a replacement.

3.5.2 *Linkages Between Assets and Services*

The linkage model (Figure 3-2) provides an initial conceptual understanding of how assets, ecosystem services and goods are related to one another in southern Alberta. The model can be further refined once more data becomes available, and during part of the process of further stakeholder consultation. Discussion of the linkages is organized by strong, moderate and weak.

Strong Linkages

A strong linkage is one where there is a high dependence between the asset and the service, in that the asset is important for providing the service or the service is important to the maintenance of the asset.

- There are strong links between natural assets (native prairie, forest and aquatic) and all four groups of ecosystem services (regulating, supporting, provisioning, and cultural). These linkages were considered strong in that these assets and services are important for the production of goods, additionally, supporting and regulating services are important for the maintenance of natural assets;

- There are strong links between agricultural assets and provisioning services that are bi-directional. There is a strong dependence of agriculture on a stable water supply and raw material inputs such as fertilizer and fuel, the production of agricultural crops, and the cultural, traditional importance of agriculture to southern Alberta;

- There are strong links between other anthropogenic assets and provisioning services due to the dependence on these assets on provisioning services for the production of goods or as inputs into the production process (e.g. stable water supply); and,

- There are strong links between other anthropogenic assets and cultural services which reflect the cultural importance of cities and rural areas, the recreational importance of commercial recreational activities and the perceived negative aesthetic impacts of industrial development on the land base in southern Alberta.

Moderate Linkages

A moderate linkage is one where there is a lesser dependence between the asset and the service, in that the asset is of lesser importance for providing the service or the service is of lesser importance to the maintenance of the asset.

- There are moderate links between geologic assets and provisioning services due to the interrelationship between ice and a stable water supply in southern Alberta, and the importance of the service of climate regulation on maintaining glaciers; and,

- There are moderate links between geological assets and cultural services in southern Alberta due to the aesthetic values associated with scenery of the Rocky Mountains and also the non-market recreational benefits they provide.

Weak Linkages

A weak linkage is one where there is a minimal dependence between the asset and the service in that the asset is of little importance for providing the service or the service is of little importance to the maintenance of the asset.

- There are weak links between agricultural assets and regulating and supporting services that indicates that the services can be supplanted and reflect significant external inputs (e.g. fertilizer) required for agricultural production in southern Alberta;

- There are weak links apparent between other anthropogenic assets and regulating and supporting services, but more data is required to assess this dependence. Many of these services are not directly important to the continued function of these anthropogenic assets, but the activities associated with these assets may be impacting services. The indirect links between these services and assets should be further explored and,

- There are weak links between supporting and regulating services and geological assets but this requires additional data to fully assess this relationship.

3.5.3 *Linkages between Services and Goods*

There are a lesser number of strong linkages between ecosystem services and goods than there are between assets and services that reflect the inter-dependence between ecosystem services and natural assets. The following generalized comments can be made regarding the linkages between ecosystem services and goods:

Strong Linkages

A strong linkage is one where there is a high dependence between the service and the production of goods, or that the service is important for the ongoing production or maintenance of the good.

- There are strong links between regulating services and the primary sector of industry in that goods such as agricultural crops, livestock and timber production depend significantly on regulating services such as climate, disturbance and water regulation to create a stable regime for production of goods;

- There are strong links between regulating services and cultural and aesthetic goods reflecting their interdependence on gas, climate, disturbance and water regulation;

- There are strong links between supporting services and the primary sector of industry as goods, such as the production of agricultural crops, that depend upon fertile soil and provision of nutrients, pollination and primary production;

- There are strong links between supporting services and cultural and aesthetic goods, largely due to the importance of maintaining future options;

- There are strong links between provisioning services and the primary and secondary sector of industry as a result of the dependence on water supply and the provision of food production and raw materials as inputs to both processes;

- There are strong links between cultural services and the tertiary sector of industry relating to linkage with the transportation (travel), trade and tourist services; and,

- Finally there are strong links between cultural services and cultural and aesthetic goods.

Moderate Linkages

A moderate linkage is one where there is a lesser dependence between the service and the production of goods, or the service is of lesser importance for the ongoing production or maintenance of the good.

- There are moderate links between regulating services and the secondary sector of industry, largely resulting from the strong dependence of this sector on primary goods;
- There are moderate links between supporting services and the secondary sector. This reflects the indirect importance of services like nutrient cycling on industries like agricultural processing; and,
- There are moderate links between provisioning services and the tertiary sector of industry, and with cultural and aesthetic goods. This reflects the dependence on some provisioning services (water supply, food production) but a lesser dependence on others (raw materials).

Weak Linkages

A weak linkage is one where there is a minimal dependence between the service and the production of goods, or the service is of little importance for the ongoing production or maintenance of the good.

- There are weak links between regulating and supporting services and the tertiary sector of industry. Many services in the tertiary sector are not directly dependent upon regulating and supporting services;
- There are weak links between cultural services and the primary and secondary sector of industry as many of the goods produced by these sectors are not dependent upon cultural services; and,
- There are weak links between supporting services and the tertiary sector. Industries in the tertiary sector depend on the regulating services only in an indirect way. The potential for attributing a higher strength to these links should be further investigated, considering the interdependence of services. For example, tertiary industry is only weakly dependent on regulating and supporting services, but moderately dependent on provisioning services. At the same time, provisioning services have a strong relationship to regulating and supporting services (Table 3-2). This may imply a stronger link between regulating/ supporting services and the tertiary sector than shown.

4.0 Role of Ecosystem Goods and Services in Southern Alberta

This section discusses the outputs of spreadsheet analyses that were completed to answer the research questions behind the EGS Assessment for southern Alberta. Each section provides a background to the analysis, discussion of relevant methods and brief discussion of key findings.

4.1 Ecosystem Services Important to the Maintenance of Assets

4.1.1 *Analytical Background*

Purpose

Table 4-1 was constructed to analyze the contribution of each ecosystem service to the maintenance of assets in southern Alberta. This analysis directly addresses the research question: *explain and summarize how the ecosystem services support the maintenance of each asset (both natural and anthropogenic).* The results are also used to create column C of Appendices 9-7 to 9-26 in the assessment of the importance of ecosystem services.

Methods

As discussed previously in Section 2.2.3, the importance of an ecosystem service to maintaining a natural asset was assigned a high, moderate or low value, based on professional opinion of the project team. A value of 1, 2, or 3 was assigned to represent low, moderate or high importance of the service to the maintenance of natural and anthropogenic assets. A service (row) was ranked as low if it did not contribute or contributed very little to the maintenance of an asset (column). The service was ranked as moderate if it contributed to a moderate degree to the maintenance of an asset. Finally, it was ranked as high if it was very important to the maintenance of an asset. The ranks low/med/high represent values of 1, 2, or 3 respectively for the purpose of summing rows (see below).

For the purposes of this analysis, the maintenance of an asset could include: 1) prevention of damage to an asset – for example, gas regulation acting in the prevention of damage to plants by ozone filtering UV radiation; 2) enhancement of asset function – for example, water regulation acting to deliver water to forests and crops; 3) existence value of a service; and, 4) protection of an asset through inherent valuation – for example, aesthetic, spiritual, education, and recreational services all tend to infer a high value on the assets on which they take place. It is assumed that people will tend to protect the areas that they value for aesthetic, spiritual, education, and recreational purposes.

After each asset was ranked with respect to a service, the entire row was summed – representing the overall rank for the service. This ranking was calculated using the 33rd and 67th percentiles for all rows. For example, if a service scored below the 33rd percentile, it was assigned low; if it scored above the 33rd but below the 67th percentile, it was assigned moderate, and if it scored above the 67th percentile it was rated as high.

4.1.2 *Findings*

All of the highest ranked services, except one, came from the category of regulating services. The regulating services are the large-scale benefits of life support functions obtained from the regulation of ecosystem processes such as gas, climate and water regulation, erosion control and sediment retention, waste treatment and biological control. These services are, by definition, important to the maintenance of assets (and in some cases to the maintenance of other services). The one high-ranking service not from the category of regulating was from provisioning services (water supply). This exception is not surprising in a semi-arid landscape.

Table 4-1 presents a summary of those ecosystem services considered to be of high or moderate importance to the maintenance of assets, followed by a discussion of potential reasons for these importance values.

Table 4-1: Summary of Ecosystem Services Considered Important to the Maintenance of Assets

Service Group	Service
Highly Important	
Regulating Services	Climate regulation Disturbance regulation Erosion control and sediment retention Waste treatment Biological control
Provisioning Services	Water supply
Moderately Important	
Supporting Services	Soil formation Primary production
Cultural and Aesthetic Services	Aesthetic Science and education

Ecosystem Services Highly Important to the Maintenance of Assets

The ecosystem services that were considered to be most important in the maintenance of assets were the regulating services of climate regulation, disturbance regulation, erosion control, waste treatment, and biological control and the provisioning service of water supply. Three of these services (climate regulation, disturbance regulation, and biological control) were also the most important with respect to the production of goods (see Section 4.2). In many cases there is an overlap in the importance to maintaining an asset and producing goods, because by maintaining an asset, that asset is in turn better positioned to provide goods.

The regulating services that protect assets from damage (climate regulation, disturbance regulation, erosion control, waste treatment, and biological control) typically all had the same (high) ranking of importance against each asset. For example, all services were of high importance to most biotic assets that involve primary production. Primary production was in turn, of high importance to the production of goods (Section 4.2).

Water supply was considered to be of high importance to the maintenance of assets. The maintenance function provided by water supply is primarily the protection and enhancement of assets via the storage and retention of water. It was not easy to separate which assets benefited from the regulating service of water regulation compared to those that benefited from the provisioning service of water supply. It is possible that some function of the regulating service was attributed to the supply service, as the two are hard to separate.

Ecosystem Services Moderately Important to the Maintenance of Assets

The supporting services of soil formation and primary production and the cultural services of aesthetic and science/education value were considered to be moderately important to the maintenance of assets.

Soil formation was seen to maintain any biotic asset dependent on soil, as well as human settlements, due to their dependence on soil for lawns, gardens, trees, and ornamental plants. Primary production was deemed as an inherent function in the production of all biotic assets.

Aesthetic and science/education were seen overall as of moderate importance to the maintenance of assets. This is because they tend to infer a high value on the assets in which they take place. It is assumed that people will tend to protect the areas that they value for aesthetic and scientific/education purposes.

4.2 Ecosystem Services and the Production of Goods

4.2.1 *Analytical Background*

Purpose

Appendix 9-4 was constructed to analyze the cumulative contribution of each ecosystem service to the production of various goods in southern Alberta. This analysis directly addresses the research question: *explain and summarize how the ecosystem services support input to production of the relevant goods.* The results are also used to feed a series of 20 intermediate tables analyzing the value of services to the production of goods (organized by asset), which is used for column B in the importance of services tables (Appendices 9-7 to 9-26).

Methods

A value of 1, 2, or 3 was assigned to represent low, moderate, or high importance of the service to the production of goods. A service (row) was ranked as low if it did not contribute or contributed very little towards the production of a good (column). The service was ranked as moderate if it contributed to a moderate degree to the production of a good. Finally, it was ranked as high if it was very important to the production of a good. The ranks low/med/high represent values of 1, 2, or 3 respectively for the purpose of summing rows (see below).

When assessing the contribution of a service to the production of a good, only goods that were directly related to the service were considered (e.g. climate regulation might directly impact agricultural crops via severe storms). Indirect relationships such the importance of food production to the oil and gas industry (via food for the workers) were not considered. This approach was taken because of the interconnected nature of ecosystem services, goods, and assets. If indirect relationships were considered, it seems likely that all services would be ranked the same and therefore very high.

A potential risk resulting from this approach is that the products produced by some lower ranked services (e.g. soil formation) may be inputs to some of the most important services (e.g. primary production). It is important when assessing the results of this study to consider all ecosystem services are interrelated. Compromising one of the (seemingly) less important services may result in indirect damages to some of the most important ecosystem services.

After each good was ranked with respect to a service, the entire row was summed – representing the overall rank for the service. This ranking was calculated using the 33rd and 67th percentiles for all rows. For example, if a service scored below the 33rd percentile, it was assigned low; if it scored above the 33rd but below the 67th percentile, it was assigned moderate, and if it scored above the 67th percentile it was rated as high.

4.2.2 *Findings*

The services that were determined to be the most important for the production of goods in southern Alberta include most of the regulating services (climate regulation, disturbance regulation, water regulation, biological control), one supporting service (primary production), and two provisioning services (water supply, and raw materials). Regulating services are importance for maintaining stable conditions necessary for the continued production of key goods.

Most of the highest ranked services can be linked directly to the task of supporting or regulating primary production. Most of the goods considered in this assessment have a high direct or indirect dependence on primary production (e.g. agriculture, forestry, subsistence, biodiversity). The provisioning service of raw materials is one highly important service that does not necessarily relate to primary production. This service was considered important due to the dependence on fuel for the production of many goods.

Future options received a high ranking in regard to all ecosystem services. It is not clear which services could be compromised (if any) without risking the loss of future options towards the production of goods provided by other services.

The value of all goods was considered equal in this initial analysis. Adding an economic coefficient of the value of production should also be considered in any future analysis of the importance of ecosystem services to southern Alberta.

Table 4-2 presents a summary of those ecosystem services considered to be of high or moderate importance to the production of goods, followed by a discussion of potential reasons for these importance values.

Table 4-2: Summary of Ecosystem Services Considered Important to the Production of Goods

Service Group	Service
Highly Important	
Regulating Services	Climate regulation Disturbance regulation Water regulation Biological control
Supporting Services	Primary production
Provisioning Services	Water supply Raw materials
Moderately Important	
Regulating Services	Gas regulation Erosion control and sediment retention Waste treatment
Provisioning Services	Genetic resources
Cultural and Aesthetic Services	Recreation

Ecosystem Services Highly Important to the Production of Goods

Primary production was considered to be of high importance to the production of a very large number of goods produced in southern Alberta (e.g. agriculture, forestry, subsistence, agricultural processing, construction, biodiversity, and aesthetics).

Water supply and raw materials were also ranked high with respect to their importance to the production of goods; water supply was ranked as the most important service overall. It is important in the production of all biotic goods (e.g. agriculture, forestry, subsistence, and biodiversity) and for other goods that may inherently require water (e.g. utilities, tourist services, aesthetic, culture, and recreation). Raw materials was deemed highly important primarily due to the importance of fuel to the production of goods, mainly driven by southern Alberta industries (agriculture, oil and gas, forestry, mining, oil and gas refining, other manufacturing, construction, transportation, and trade).

The regulating services that were deemed most important to the production of a large number of goods were, in most cases, directly responsible for protecting the function of primary production. For instance: the function of disturbance regulation in protecting crops and forests from extreme weather events, the function of climate regulation in stabilizing the earth's temperature and protecting biodiversity, and the function of water regulation in providing a stable and reliable source of water for agriculture and biota in southern Alberta. The regulating service of biological control was also considered important to the production of agricultural goods.

Ecosystem Services Moderately Important to the Production of Goods

It is important to note that several regulating services that received moderate rankings (erosion control, waste treatment, soil formation, nutrient cycling, pollination) are directly responsible for supporting services that are highly ranked (mainly primary production). This underscores the importance of the interrelationships between ecosystem services.

Genetic resources received an overall moderate ranking due to its high importance in relation to agriculture-crop and agriculture-livestock and future options. Recreation also received a moderate ranking largely as a result of the importance of this service to the production of a number of goods in southern Alberta.

4.3 Impact of the Expansion of Anthropogenic Assets on Ecosystem Services

Purpose

The relationship between ecosystem services and the associated goods they provide is described in previous sections. Changes to the amount of natural assets present on the landscape may affect the relative abundance of a range of ecosystem services that in turn provide important and highly valued societal goods. The following analysis addresses the research question: e*xplain and summarize the relative impact of expanding anthropogenic assets on the capacity of the natural assets to continue to provide ecosystem services, and the capacity of the natural assets to continue to produce the goods.*

Methods

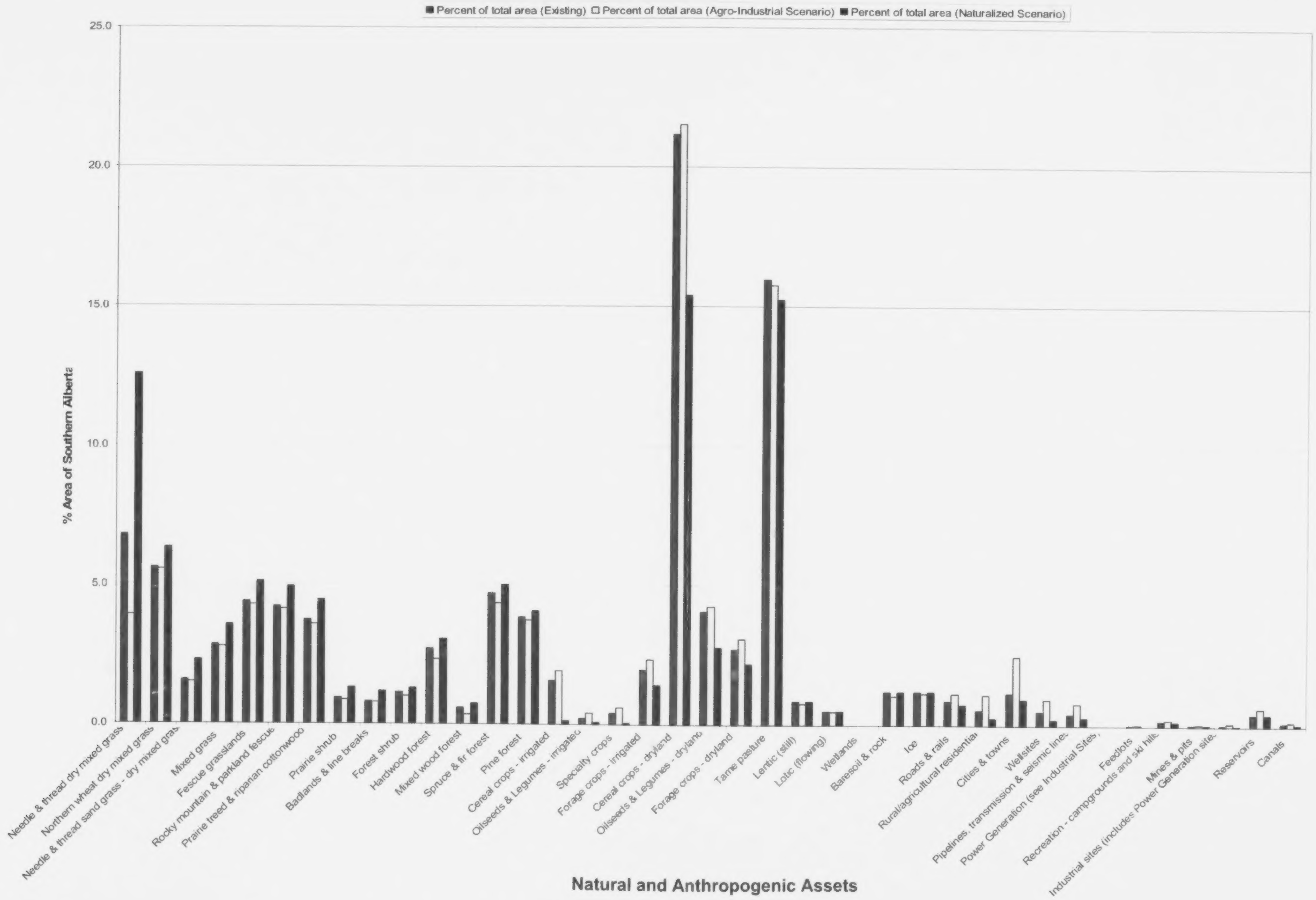
In order to demonstrate both the importance of the relationships and to illustrate potential impacts of changes to natural assets, two scenarios of future regional change are presented and compared to the existing conditions. Neither scenario is meant to be realistic but, rather, has been constructed to demonstrate relationships and potential impacts. The first scenario (the Agro-industrial Scenario) increases the amount of industrial activities and arable agriculture, while the second (the Naturalized Scenario) converts anthropogenic cover types into natural cover types through restoration (Figure 4-1).

The following charts indicate the percentage of the region that each asset type occupies under the different scenarios described below.

Under the Agro-industrial Scenario there is a decrease in native prairie assets, forest assets, tame pasture, lotic water and lentic water and a corresponding increase in cereal, oilseeds and legumes, specialty crops, forage crops and other anthropogenic assets.

In the Naturalized Scenario there are decreases in agricultural assets, roads and rails, rural/agricultural residential, cities, well sites, pipelines, feedlots, recreation sites, industrial sites, canals and increases in native prairie and forest assets. The changes to projected services and goods are analysed in following sections. Methodological approaches are also presented.

Figure 4-1: Assets as a Percentage of Southern Alberta



4.3.1 *Capacity of Assets to Provide Services*

As the concept of ecosystem services has not been widely publicized, the understanding of the importance of the services provided by assets is not clearly understood by the general public. Appropriate mechanisms need to be in place for both valuing these services and providing incentives to ensure their maintenance (see Section 5). The first step is to conceptualize the potential impacts on services of converting from natural to anthropogenic assets.

Expansion of anthropogenic assets at the expense of natural assets may change the quantity, quality and type of ecosystem services provided by southern Alberta.

An index of service provision was developed and evaluated according to the existing composition of assets in the region and for the two opposing scenarios (Agro-industrialization and Naturalization). The index was developed as follows:

$$\text{Provision of Service 1 in Southern Alberta} = \frac{(A_1 \times S_{A1}) + (A_2 \times S_{A2}) + \ldots + (A_{35} \times S_{A35})}{200}$$

Where,

A_x = % Asset x in Southern Alberta

S_{Ax} = Importance of Asset x to providing Service 1

The importance of each asset to providing the service is ranked on a relative scale of -2 to +2, depending on whether the asset depletes the service, has no effect on the service, or provides the service (Appendix 9-5: Importance of Assets to the Provision of Services). For example, mixed grass is highly important (+2) to providing soil formation while dryland cereal crops are moderately detrimental (-1) and cities and towns are highly detrimental (-2) to soil formation. Thus a region composed of 50% mixed grass, 40% cereal crops and 10% urban would have a value in the numerator of 50*2 + 40*(-1) + 10*(-2) = 40.

The value of the denominator (200) is the maximum theoretical value for provision of Service 1 in southern Alberta given a landscape in which 100% of the land base is ranked highly important (+2) to providing the service. The reverse is also possible, where 100% of the land base is ranked highly detrimental (-2) to the provision of the service. This case would be designated by a negative numerator. Dividing the total numerator by 200 normalizes the index to a relative ranking of -1 to +1. Thus, in the mixed grass/cereal crop/city example, the index of provision of soil formation in the region is given a value of 40/200 = 0.2.

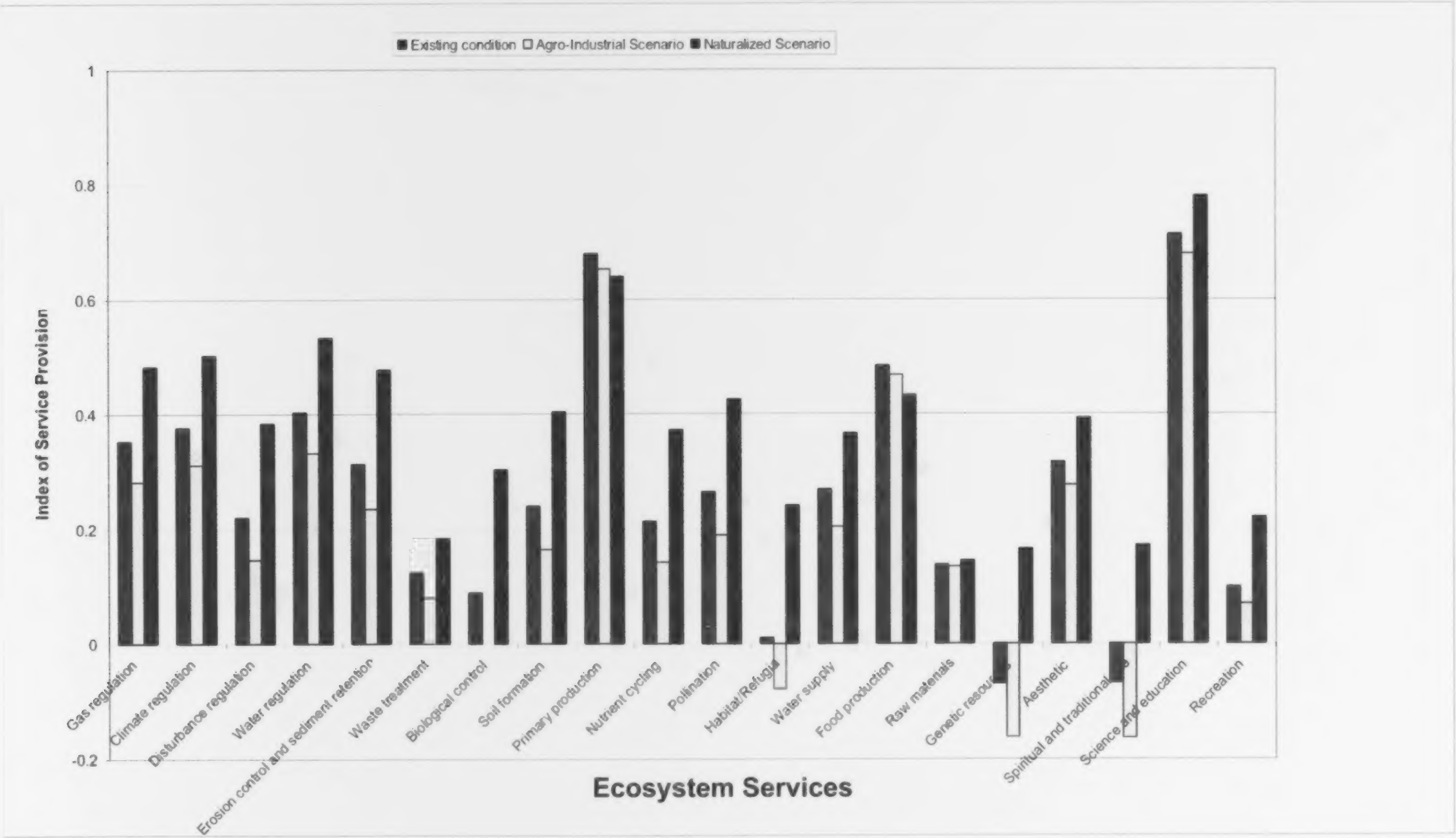
The index can therefore be considered a type of area-weighted importance index for the provision of ecosystem services across southern Alberta. The results of applying this index to the 20 identified ecosystem services under existing conditions and two alternative scenarios are shown in Figure 4-2.

The current state of ecosystem services in southern Alberta is moderate, with the highest index values occurring for the services primary production, food production, and science and education. Currently there are low values for habitat/refugia, genetic resources and spiritual and traditional use. According to this method of analysis, the latter two services are actually in slight decline under the current land use/land cover composition in southern Alberta. In other words there are more negative effects on genetic resources and spiritual / traditional uses than positive.

In the Agro-industrial Scenario (Enhanced Agriculture and Anthropogenic), in which anthropogenic assets are increased at the expense of natural assets, the index of service provision in southern Alberta decreases to varying degrees for all ecosystem services. The greatest decreases are seen for the services biological control, habitat/refugia, genetic resources and spiritual and traditional use. Habitat/refugia also becomes a net loss under this scenario. The services primary production, food production, raw materials and recreation show the smallest decreases compared to the other ecosystem services, since these services can be provided to some extent by anthropogenic assets. For example, primary production and food production can both be provided by agricultural land, which expands under this scenario along with the expansion of urban and residential areas. Decreasing the percentage of native grasslands on the landscape has the greatest impact on many of the ecosystem services in the Agro-industrial Scenario. All services, except for raw materials provision, are strongly decreased by the decrease in this set of natural assets. The expansion of cities and towns onto native prairie assets appears to have the greatest influence on the decrease in ecosystem services.

Similarly, the greatest increases in ecosystem services under the Naturalized Scenario can be attributed to the increase in native prairie assets through conversion of arable agricultural lands back to a natural state. Increasing the proportion of native assets on the landscape causes the services of biological control, habitat/refugia, genetic resources and spiritual and traditional use to show the highest corresponding increases in service provision. The smallest increases are shown with respect to waste treatment and raw materials; two services, primary production and food production actually show a slight decrease under this scenario. This effect can be attributed to the large-scale conversion of arable agriculture, forage and tame pasture back into native prairie assets.

Figure 4-2: Index of Services Provided by Assets



Looking at the individual ecosystem services and how they change in the two opposite scenarios reveals the following:

Gas regulation is provided by all grassland assets, due to their ability to regulate carbon dioxide fluxes between the atmosphere and soil. Forests, while less abundant in southern Alberta, are also highly important in providing gas regulation through their large quantity of biomass. Gas regulation is most negatively impacted by cities and towns, well sites, feedlots, mines and pits, and industrial sites, and is only slightly less impacted by arable agriculture assets that disturb the soil and release stored carbon to the atmosphere. However, arable agriculture covers a much greater proportion of southern Alberta which increases the relative impact of expanding agriculture on this ecosystem service in the Agro-industrial Scenario. In the Naturalized Scenario, conversion of cereal crops into native grasslands is the largest driver behind the increase in gas regulation;

Climate regulation is similar to gas regulation in that it is provided primarily by native grasslands and forests, and to a lesser degree by lentic water, wetlands and reservoirs. Conversion of native grassland to urban areas strongly decreases climate regulation in the Agro-industrial Scenario. In the Naturalized Scenario, the greatest increase in climate regulation comes from the restoration of grassland assets from cereal crops;

Disturbance regulation is provided mainly by native prairie assets including prairie treed and cottonwood complexes; forest shrubs; and mixedwood and hardwood forests. Canals are an anthropogenic asset that is also highly important to providing disturbance regulation. Prairie disturbance regulation is provided to a lesser extent by natural aquatic assets. In the Agro-industrial Scenario, disturbance regulation is decreased by the expansion of urban areas onto native prairie, which is compensated only very little by the small increase in canals. Disturbance regulation is improved in the Naturalized Scenario by decreasing cereal crops on native prairie;

Water regulation is provided primarily by native prairie assets including cottonwood complexes; forests; aquatic assets; and also by the anthropogenic assets reservoirs and canals. Cities and towns, mines and pits, and industrial sites have the greatest relative negative impact on water regulation in the landscape. In the Agro-industrial Scenario, water regulation is decreased mainly by the expansion of urban areas onto native prairie assets. In the Naturalized Scenario, an increase in native prairie relative to arable cropland increases the provision of water regulation;

Erosion control and sediment retention is highly impacted by roads and rails, cities, mines and pits, and industrial sites, while agricultural assets deplete the service to a lesser degree. Erosion control and sediment retention decreased to the greatest extent in the Agro-industrial Scenario by the expansion of cities onto native prairie. Agricultural assets converted to native prairie assets in the Naturalized Scenario increases the provision of erosion control as a service in the landscape;

Waste treatment is negatively impacted by the expansion of cities onto native prairie in the Agro-industrial Scenario. In the Naturalized Scenario, waste treatment shows one of the smallest relative increases compared with the other ecosystem services with the restoration of native prairie;

Biological control shows one of the greatest decreases with the expansion of anthropogenic assets (particularly cities and towns) in the Agro-industrial Scenario as well as one of the greatest increases in service provision with the restoration of native assets (particularly native grasslands);

Soil formation is most negatively impacted by the expansion of cities and towns onto native prairie in the Agro-industrial Scenario, and most positively affected by the restoration of native prairie compared to existing conditions in the Naturalized Scenario;

Primary production has one of the highest index values of all services currently provided in southern Alberta. Expanding anthropogenic assets in the Agro-industrial Scenario causes only a small decrease in primary production. The loss of primary production, due mainly to the increase in urban areas, is offset by an increase in agricultural land which provides primary production. Anthropogenic assets that can slightly increase primary production include reservoirs and canals. Restoring natural assets in the Naturalized Scenario also causes a small decrease in primary production, resulting from the decrease in arable agriculture, forage crops, tame pasture and canals;

Nutrient cycling is most impacted by the expansion of cities and towns onto native prairie in the Agro-industrial Scenario, while the conversion of arable agriculture to native prairie in the Naturalized Scenario increases nutrient cycling in the region. Forage crops and tame pasture, as anthropogenic assets, do provide a moderate amount of nutrient cycling;

Pollination is negatively impacted by the expansion of cities and towns onto native prairie in the Agro-industrial Scenario, while the conversion of arable agriculture to native prairie in the Naturalized Scenario increases pollination services in the region. Again, forage crops and tame pasture provide a moderate amount of nutrient cycling;

Habitat/Refugia is currently one of the least provided services in southern Alberta according to the index. This service is also one of the most sensitive to expansion of anthropogenic assets or restoration of natural assets. Expansion of urban areas and cropland into native prairie strongly decreases habitat/refugia in the region, while the conversion of arable agriculture back to native prairie strongly increases the service. Tame pasture has a moderate effect on the service compared with arable agricultural assets;

Water supply is negatively affected by the expansion of cities and towns in the Agro-industrial Scenario, especially on native prairie. Creation of reservoirs has a slight positive effect on water supply, but this does not counteract the negative impacts because the area of reservoirs is still relatively small. In the Naturalized Scenario, restoration of native prairie and conversion of cereal crops (particularly irrigated cereal crops) increases water supply as an ecosystem service;

Food production is currently relatively high in southern Alberta compared with other ecosystem services. In the Agro-industrial Scenario, the decrease in this service is relatively small due to the expansion of agricultural assets and feedlots as well as urban assets. In the Naturalized Scenario, there is also a small decrease in food production associated with the decrease in agriculture and conversion to native prairie;

Raw materials provision shows one of the smallest relative decreases with the expansion of anthropogenic assets in the Agro-industrial Scenario, because of the capacity of several anthropogenic assets to provide raw materials (e.g., well sites, pipelines, mines, industrial sites). The decrease in forest assets such as hardwood and spruce/fir forest due to road and town expansion most strongly impacts the provision of this service. Conversely, the restoration of hardwood forests in the Naturalized Scenario increases the provision of raw materials, but to a small degree overall due the associated decrease in well sites, pipelines and industrial sites;

Genetic resources provision is currently given a negative index value in southern Alberta, indicating that genetic resources are actually decreasing under current land cover/land use composition. This service is also one of the most sensitive to expansion of anthropogenic assets or restoration of natural assets. Expansion of urban areas and cropland into native prairie strongly decreases genetic resources in the region, while the conversion of arable agriculture and forage crops back to native prairie strongly increases the service;

Aesthetic services are considered to be negatively affected by the decrease in native prairie in the Agro-industrial Scenario, although the creation of recreation areas, reservoirs and canals has a slightly positive counter-balancing effect. In the Naturalized Scenario, restoration of native prairie increases aesthetics as an ecosystem service;

Spiritual and traditional use is currently given a negative index value in southern Alberta, indicating that spiritual and traditional uses are actually decreasing under current land cover/land use composition. This service is also one of the most sensitive to expansion of anthropogenic assets or restoration of natural assets. Expansion of anthropogenic assets into native prairie strongly decreases spiritual and traditional resources in the region, while the conversion of arable agriculture back to native prairie strongly increases the service;

Science and education is currently relatively high in southern Alberta compared with other ecosystem services, because of the ability of this service to be provided by a variety of assets. In the Agro-industrial Scenario, the decrease in science and education is due primarily to the expansion of cities and towns onto native prairie; expansion of cropland and recreational areas give very slight increases in science and education. In the Naturalized Scenario, there is an increase in science and education services associated with the increase in native prairie assets. However, the decrease in the service due to the decrease in area of cities and recreational sites lowers the magnitude of the service increase; and,

Recreation experiences one of the smallest relative decreases in service provision with respect to the expansion of anthropogenic assets in the Agro-industrial Scenario. Here, the decrease in the service associated with the decrease in native prairie and forest assets is lessened by the slightly positive changes associated with increasing roads and rails, recreation areas, reservoirs and canals. Restoring natural assets in the Naturalized Scenario causes a slight increase in recreation services, resulting from the decrease in arable agriculture and increase in native prairie assets.

4.3.1 *Capacity of Assets and Services to Provide Goods*

The second part of the research question regarding the impacts of expansion of anthropogenic assets deals with the capacity of the assets and services to provide goods. This part of the question was assessed through two complementary analyses: one that looked at the direct effect of expanding anthropogenic assets on natural assets and the goods provided by those assets; and one that examined the effect that the change in assets would have on the ecosystem services required for sustained production of those goods.

Capacity of Assets to Directly Produce Goods

The first analysis, the direct production of goods from assets, was assessed using a similar index to that developed in Section 4.3.1. The direct production analysis assumes the contribution of all inputs including ecosystem services as well as external inputs such as fertilizer, fuel, etc.

An index of good production was developed and evaluated according to the existing composition of assets in the region and for the two opposing Scenarios (Agro-industrial expansion and Naturalization).

The index was developed as follows:

$$\text{Production of Good 1 in Southern Alberta} = \frac{(A_1 \times G_{A1}) + (A_2 \times G_{A2}) + \ldots + (A_{35} \times G_{A35})}{300}$$

Where,

A_x = % Asset x in Southern Alberta

G_{AX} = Importance of Asset x to providing Good 1

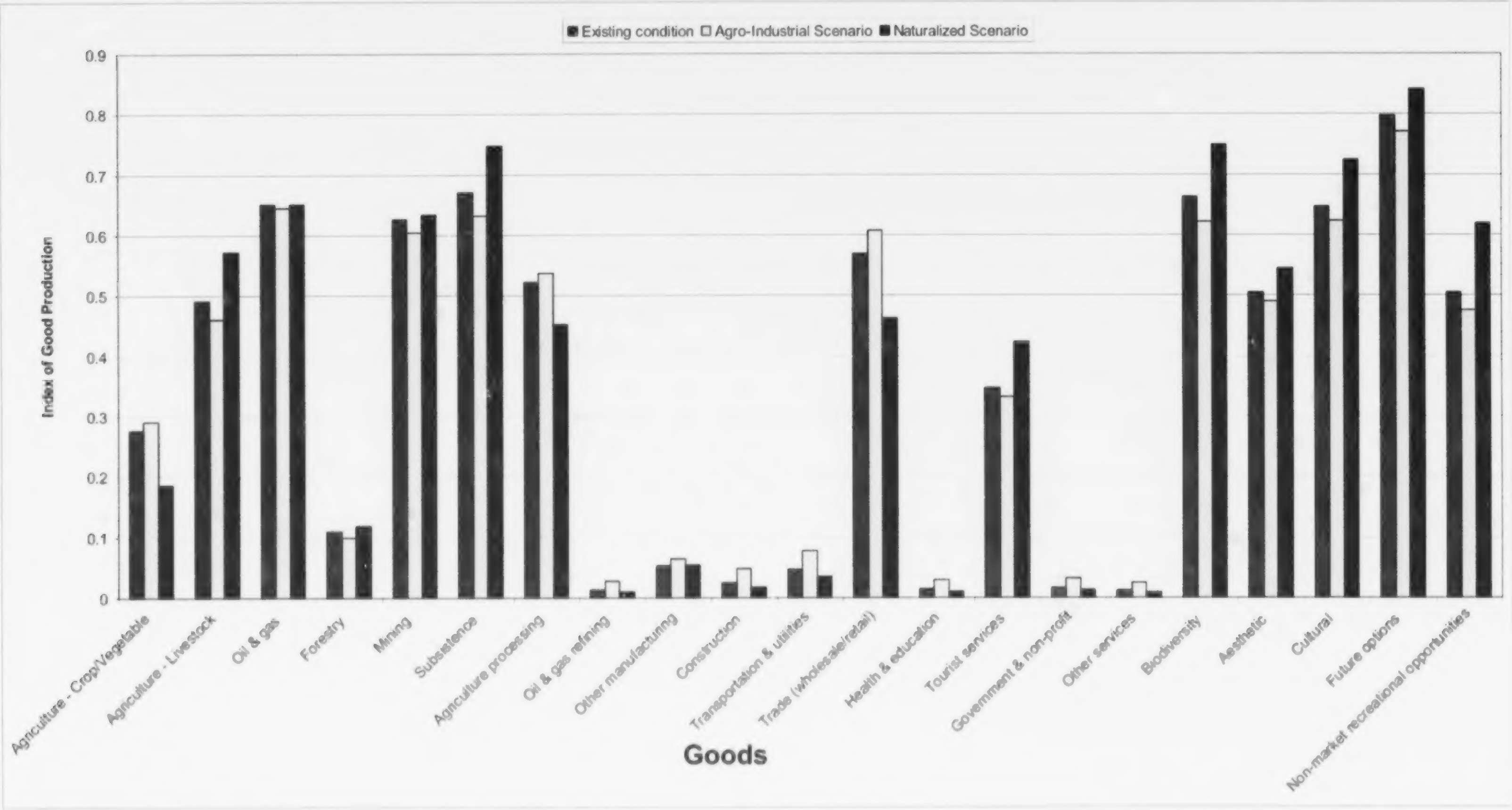
The importance of each asset to providing the good is ranked on a relative scale of 0 to 3, where 3 is highly important, 2 is moderately important, 1 is low importance, and 0 means that the good is not produced by that asset (Appendix 9-6: Importance of the Asset to the Production of Goods). Using the example of mixed grass, cereal crops and urban areas once more, it can be seen that mixed grass and cities and towns have no importance (0) to crop/vegetable production, while cereal crops are highly important (3) to producing crop/vegetable goods. The hypothetical region with 50% mixed grass, 40% cereal crops and 10% cities and towns would have a value in the numerator of 50*0 + 40*3 + 10*0 = 120.

The value of the denominator (300) is the maximum theoretical value for production of a good in southern Alberta, given a landscape in which 100% of the land base is ranked highly important (3) to providing the good. Dividing the total numerator by 300 normalizes the index to a relative ranking of 0 to 1. Thus, the mixed grass/cereal crop/city example gets an index value of 120/300 = 0.4 for the production of crop/vegetables.

Similar to the index of service provision, the index of good production can therefore be considered a type of area-weighted importance index for the production of goods by the land base across southern Alberta. The results of applying this index to the 21 identified goods under existing conditions and for the two scenarios are shown in Figure 4-3.

An artefact that is immediately apparent from looking at Figure 4-3 is the very small index values associated with most of the secondary and tertiary sector goods. This is a result of the fact that provision of these goods is not directly dependent on most assets. The opposite is true for the goods in the primary sector and the non-market goods (biodiversity, aesthetic, cultural, future options, non-market recreational opportunities). In addition, the index is area-weighted and does not reflect the per hectare importance value (see note below).

Figure 4-3: Index of Goods Directly Provided by Assets in Southern Alberta



NOTE: The calculation of the index of goods directly produced by assets does not include an importance coefficient that would adjust the area weighted calculation for the importance to society of that good. The coefficient may be calculated based on economic importance and/or societal importance as developed through consultation for non-market goods.

An example of how the importance coefficient would fit into the equation is:

Provision of Good 1 in southern Alberta =

$$\frac{(A_1 \times G_{A1} \times I_{A1G1}) + (A_2 \times G_{A2} \times I_{A2G1}) + \ldots + (A_{35} \times G_{A35} \times I_{A35G1})}{300}$$

Where,

A_x = % Asset x in southern Alberta

G_{Ax} = Importance of Asset x to providing Good 1

I_{AXG1} = Societal/economic importance coefficient for rating the importance of Good 1 produced by Asset x (between 0 and 1)

This coefficient is required for future planning efforts in order to allow for direct comparison and trade-offs between goods produced but is beyond the scope of the current work.

The production of oil and gas, mining, and subsistence show high index values in Figure 4-3, because they can occur across much of the existing land base irrespective of the asset itself. Similarly, agriculture has a higher value than forestry because agricultural land takes up a much larger proportion of southern Alberta than forest assets. Agricultural processing is also high due to the immediate connection to the agricultural land base. Wholesale and retail trade, as the link between the primary sector goods and the secondary sector, depends on the goods produced by the land base and is also relatively high.

In the Agro-industrial Scenario, in which anthropogenic assets are increased, there is a corresponding increase for production of several of the goods, including: crop/vegetable agriculture; agricultural processing; oil and gas refining; other manufacturing; construction; transportation and utilities; trade; health and education; government and non-profit; and other services. Goods that decrease as anthropogenic assets expand include: livestock agriculture; oil and gas; forestry; mining; subsistence; tourist services; biodiversity; aesthetic goods; cultural goods; future options; and non-market recreation.

Capacity of Ecosystem Services to Produce Goods

For the second analysis, the potential for the production of goods to be produced through ecosystem services, a third index was developed based on the ecosystem services provided by southern Alberta (as determined by the index of service provision – see Section 4.3.1) and the importance of those services to producing goods (as determined in Appendix 9-4: Importance of the Service to the Production of Goods). This index of ability of ecosystem services to provide goods was developed and evaluated according to the existing land use/land cover composition of the region and for the two opposing scenarios.

The index was developed as follows:

Ability of Ecosystem Services to Produce Good 1 in southern Alberta =

$$\frac{(S_1 \times G_{S1}) + (S_2 \times G_{S2}) + \ldots + (S_{20} \times G_{S20})}{60}$$

Where,

S_x = Provision of Service x in southern Alberta (from index of service provision – 4.3.1)

G_{SX} = Importance of Service x to producing Good 1

Provision of each service in southern Alberta is taken directly from the result of calculating the index of service provision in Section 4.3.1. For instance, provision of soil formation in the mixed grass/cereal crop/city example was calculated to be 0.2 (see Section 4.3.1). A second service, habitat/refugia has a service provision index value of 0, while a third service, pollination, has a service provision index value of 0.2.

The importance of each service to providing Good 1 is ranked on a relative scale of 1 to 3, where 3 is highly important, 2 is moderately important and 1 is low to no importance (see Table 4-3 "Importance of the Service to the Production of Goods"). Soil formation, for example, has a high importance (3) to providing crop/vegetable agriculture, while habitat/refugia has low importance (1) and pollination has a high importance (3). The value of the numerator for the mixed grass/cereal crop/city example thus becomes 0.2(3)soil formation + 0(1)habitat/refugia + 0.2(3)pollination = 1.2

The value of the denominator (60) is the maximum theoretical value for the ability of ecosystem services to produce Good 1 in southern Alberta, if the index of provision for each of the 20 services was 1 and each service was ranked highly important (3) to production of the good. Dividing the total numerator by 60 normalizes the index to a relative ranking of 0 to 1. While this is the theoretical maximum, it should be noted that achieving a value of 1 for any given good will be unattainable for all practical purposes, since the probability of arriving at a landscape composition where all 20 ecosystem services are provided to their maximum extent is extremely unlikely. In the mixed grass/cereal crop/city example, the index of the ability of ecosystem services to provide goods becomes 1.2/60 = 0.02.

The results of applying this index to the 21 identified goods are shown in Figure 4-4.

Figure 4-4: Index of Long-Term Ability of Ecosystem Services to Produce Goods

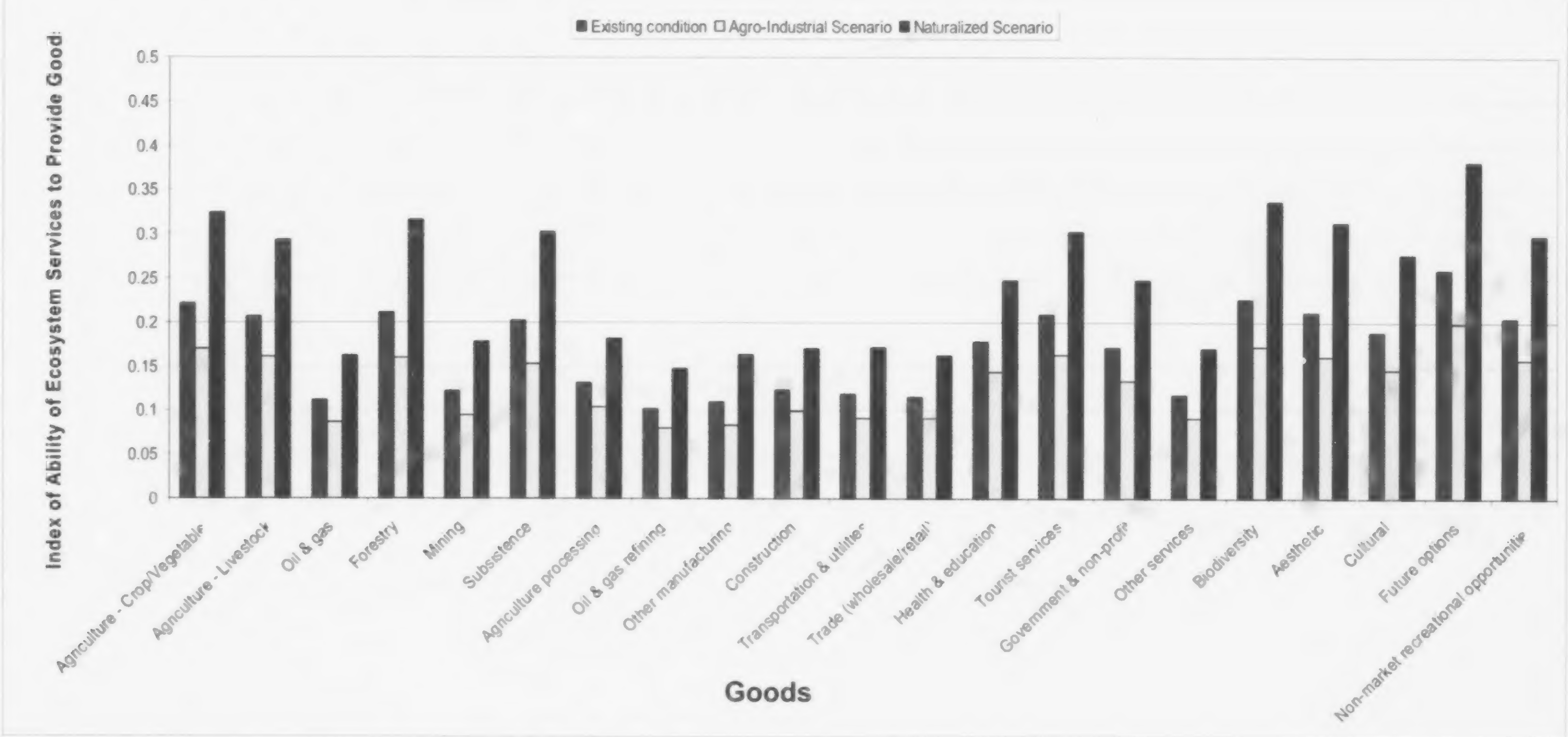


Figure 4-4 indicates the degree to which services required for production of goods are provided by ecosystems in the region. For example, services of high importance to the production of crop/vegetable agriculture include gas regulation; climate regulation; disturbance regulation; water regulation; erosion control and sediment retention; waste treatment; biological control; soil formation; primary production; nutrient cycling; pollination; water supply; food production; raw materials; and genetic resources (Appendix 9-4: Importance of the Service to the Production of Goods). Each of these services is provided to a different extent in southern Alberta, under current conditions and under the Agro-Industrial and Naturalized Scenarios (Figure 4-2), contributing to the ability in southern Alberta to sustain production of crop/vegetable agriculture over the long term. Any services not provided by ecosystems (e.g., nutrient cycling) must be subsidized through artificial services (e.g., added fertilizer).

Impacts on Goods in Southern Alberta

The sustained production of goods in southern Alberta depends on both the capacity of assets and services to produce goods. The impacts of expanding anthropogenic assets in the Agro-industrial Scenario and restoring natural assets in the Naturalized Scenario are explained further with respect to the 21 goods/sectors identified in southern Alberta:

Agriculture – Crop/Vegetable production depends highly on the area of arable agriculture assets. Canals and rural/agricultural residential assets have a low importance to crop/vegetable production. Crop/vegetable agriculture increases in the Agro-industrial Scenario as agricultural assets, both irrigated and dryland, expand over native prairie (Figure 4-3). However, the ecosystem services ranked as highly important to crop/vegetable production (e.g., gas regulation, nutrient cycling) are decreased under the Agro-industrial Scenario. The ability of ecosystem services to produce this good shows one of the largest relative decreases under the Agro-industrial Scenario (Figure 4-4). In the Naturalized Scenario, the direct production of crop/vegetable agriculture from assets strongly decreases while the potential for ecosystem services to provide this good increases. There is an inverse relationship between the production of the good from the asset and the ability of ecosystem services to provide the good. This is in direct contrast to the index of goods directly produced by assets (including external inputs) calculated previously, which showed an increase in agricultural goods as agriculture increases. In other words, as traditional arable agriculture increases in the area, it decreases the ecosystem services (e.g., nutrient cycling, erosion control) that are fundamental to the long-term production of agricultural goods. This is offset through external inputs such as fertilizer. The sustainability of expansion of arable agriculture is therefore in question.

Agriculture – Livestock production is more widespread across different assets, occurring on native prairie assets as well as tame pasture and feedlots. The index of production of the good is therefore higher than that of crop/vegetable agriculture because the area of assets important to producing livestock is greater. In the Agro-industrial Scenario, the production of livestock decreases slightly because of the reductions in area of native prairie and expansion of arable agriculture and urban areas. Livestock production increases highly in the Naturalized Scenario as a result of increased native prairie assets. Livestock agriculture depends highly on ecosystem services including gas regulation, climate regulation, water regulation, waste treatment, biological control, primary production, water supply, food production and genetic resources. The ability of these services to produce livestock agriculture decreases with the expansion of anthropogenic assets in the Agro-industrial Scenario and increases with the restoration of native prairie systems in the Naturalized Scenario. In both scenarios, there is a direct relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Oil and gas as a primary sector good is widespread across most assets, and differentiates little between assets as it can be found under almost any of the southern Alberta assets. Oil and gas production decreases slightly in the Agro-industrial Scenario with the expansion of cities, and increases slightly under the Naturalized Scenario. Oii and gas production also has little dependence on most ecosystem services with the exception of raw materials. Thus it shows the least decrease with respect to the ability of ecosystem services to provide the good in the Agro-industrial Scenario. Under the increase in ecosystem services provided by the Naturalized Scenario, it shows a slight increase. In both scenarios, there is a direct relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Forestry is highly dependent on forest assets for production, which represent a relatively small proportion of southern Alberta. Forestry decreases in the Agro-industrial Scenario with the expansion of urban areas, well sites and industrial sites, and increases with the restoration of forest assets in the Naturalized Scenario. Forestry is highly dependent on several ecosystem services including gas regulation, climate regulation, disturbance regulation, water regulation, erosion control, biological control, soil formation, primary production, nutrient cycling, water supply, raw materials and genetic resources. The ability of these services to produce forestry as a good shows a moderately high decrease under the Agro-industrial Scenario due to the conversion of natural assets that provide these services, and a very high increase under the Naturalized Scenario. In both scenarios, there is a direct relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Mining is very similar to oii and gas as it is widespread across most assets. Mining decreases slightly in the Agro-industrial Scenario with the expansion of cities into potential mining areas, despite the increase of mines and pits as an asset because the footprint of mines and pits is relatively very small. Mining, as a good, increases slightly in the Naturalized Scenario with the restoration of natural assets that may be possible to mine. Mining is highly dependent on erosion control and raw materials as ecosystem services, which show a slight decrease under the Agro-industrial Scenario and a slight increase under the Naturalized Scenario. In both scenarios, there is a direct relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Subsistence depends on the area of natural assets such as native prairie and forest in southern Alberta. In the Agro-industrial Scenario, subsistence shows a substantial decrease in good production due to the expansion of cropland and urban areas; in the Naturalized Scenario, subsistence increases with the restoration of natural assets. The increase in ecosystem services in the Naturalized Scenario also greatly increases the ability of these services to produce subsistence as a good. Subsistence is highly dependent on many ecosystem services: gas, climate, disturbance and water regulation; biological control; primary production; habitat/refugia; water supply; and spiritual and traditional use. The ability of these services to produce subsistence decreases in the Agro-industrial Scenario. There is a direct relationship between the production of the good from the asset and the ability of ecosystem services to provide the good in both scenarios.

Agriculture processing is strongly dependent on agricultural assets in the landscape, despite being a secondary sector good. Agriculture processing increases in the Agro-industrial Scenario with the increase in the proportion of cropland in southern Alberta, and shows a large decrease in the Naturalized Scenario. Primary production is the only ecosystem service upon which agriculture processing is highly dependent. The ability of ecosystem services to support agriculture processing decreases in the Agro-industrial Scenario and increases in the Naturalized Scenario. There is therefore an inverse relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Oil and gas refining is produced by only a few assets (cities and towns, pipelines and industrial sites) covering a very small proportion of the landscape, thus the index of good production is very small. Oil and gas refining increases in the Agro-industrial Scenario with the expansion of cities, pipelines and industrial sites, and decreases in conjunction with the decrease of these assets in the Naturalized Scenario. Since raw materials is the only ecosystem service upon which oil and gas refining is highly dependent, the ability of ecosystem services to provide the good changes little in the Agro-industrial Scenario (decrease) and the Naturalized Scenario (increase). In both scenarios, there is an inverse relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Other manufacturing is also produced by few assets (forest assets, cities and towns, pipelines, feedlots, mines and industrial sites). The footprint of these assets is relatively small, thus the index of good production is very small. Expansion of cities and towns in the Agro-industrial Scenario increases other manufacturing as a good. Other manufacturing depends primarily on the services raw materials and genetic resources: the ability of these ecosystem services to produce manufacturing decreases in the Agro-industrial Scenario and increases in the Naturalized Scenario. In both scenarios, there is an inverse relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Construction is similar to other manufacturing: its area-weighted production on the landscape is very small, as it is occurs on few assets making up a relatively small proportion of southern Alberta (rural/agricultural residential, cities, well sites, pipelines, feedlots, recreation sites, mines, industrial sites, reservoirs and canals). As these are all anthropogenic assets, construction increases with expanding anthropogenic assets in the Agro-industrial Scenario. Construction decreases in the Naturalized Scenario, with the greatest change being effected through the decrease in urban area. Construction depends highly on the ecosystem services primary production and raw materials. The ability of these services to provide construction decreases very little in the Agro-industrial Scenario and shows a small increase in the Naturalized Scenario. There is an inverse relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Transportation and utilities is primarily dependent on anthropogenic assets with a relatively small footprint, including roads/rails, rural/agricultural residential, cities, well sites, pipelines, industrial sites and reservoirs. These assets increase in the Agro-industrial Scenario, which strongly increases transportation and utilities as a good.

Transportation and utilities decrease in the Naturalized Scenario. This good depends highly on water supply and raw materials as ecosystem services, which causes the ability of these services to provide the good to decrease in the Agro-industrial Scenario and increase in the Naturalized Scenario. In both scenarios, there is an inverse relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Trade (wholesale/retail) is the link between the primary sector goods and the secondary sector, and is thus dependent on many of the assets in southern Alberta. This good shows the greatest increase with the increase in anthropogenic assets (especially urban expansion) in the Agro-industrial Scenario and also shows a relatively large decrease in the naturalized region of the Naturalized Scenario. Since the only ecosystem service upon which trade depends highly is raw materials, the ability of ecosystem services to provide trade decreases only slightly in the Agro-industrial Scenario and increases only slightly in the Naturalized Scenario. There is a strong inverse relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Health and education depends primarily on cities and towns as an asset, which occupy a relatively small proportion of land. With the expansion of cities in the Agro-industrial Scenario, health and education increases. It then decreases with the opposite situation in the Naturalized Scenario. The ability of ecosystem services (primarily gas regulation, waste treatment, biological control, primary production, science and education and recreation) to provide health and education decreases in the Agro-industrial Scenario and increases in the Naturalized Scenario. Again, there is an inverse relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Tourist services are moderately to highly dependent on natural assets as well as anthropogenic ones, including native prairie assets, forest assets and aquatic assets. Thus, tourist services decrease with the expansion of anthropogenic assets in the Agro-industrial Scenario. Tourist services increase in the naturalized landscape of the Naturalized Scenario despite the decrease in cities and towns, because of the relatively larger area occupied by natural assets. Ecosystem services highly associated with tourist services include: gas, climate, and disturbance regulation; biological control; primary production; water supply; aesthetic services; spiritual and traditional use; science and education; and recreation. The ability of these services to provide tourist services as a good decreases as the proportion of anthropogenic assets increases. The relationship is direct between the production of the good from the asset and the ability of ecosystem services to provide the good.

Government and non-profit depends primarily on cities and towns as an asset, similar to health and education. With the expansion of cities in the Agro-industrial Scenario, government and non-profit increases as a good. It then decreases with the opposite situation in the Naturalized Scenario. The ability of ecosystem services (primarily gas regulation, climate regulation, disturbance regulation, biological control and recreation) to provide government and non-profit decreases in the Agro-industrial Scenario and increases in the Naturalized Scenario. There is an inverse relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Other services are produced by cities and towns, so any increase in the proportion of urban areas in southern Alberta will increase the production of this good. However, the ability of ecosystem services to provide the good decreases with expansion of anthropogenic assets onto natural assets. Thus there is an inverse relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Biodiversity is a good that is highly dependent on natural assets in southern Alberta. Thus, this good shows the largest decline of all the goods in the Agro-industrial Scenario with the expansion of anthropogenic assets. Biodiversity also shows a large increase in the Naturalized Scenario. Similarly, the ability of ecosystem services to provide biodiversity decreases heavily in the Agro-industrial Scenario and increases considerably in the Naturalized Scenario. Biodiversity is highly dependent on most ecosystem services (gas, climate, disturbance, and water regulation; erosion control; biological control; soil formation; primary production; nutrient cycling; pollination; habitat/refugia; water supply; genetic resources; and science and education). There is a direct relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Aesthetic goods, similar to biodiversity, tend to be tied to natural assets. Thus, as anthropogenic assets such as cropland, mines and well sites expand onto natural assets, the production of aesthetic goods decreases. Restoring native assets in the Naturalized Scenario conversely increases the production of aesthetic goods. Aesthetics are highly dependent on regulating services including gas, climate, disturbance and water regulation as well as other ecosystem services including primary production, pollination, water supply, aesthetic services, spiritual and traditional use, and recreation. As the provision of these services decrease in the Agro-industrial Scenario, so does their ability to provide aesthetic goods. The ability of ecosystem services to provide aesthetic goods strongly increases in the Naturalized Scenario. There is a direct relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Cultural goods are highly dependent on natural assets, but are also dependent on anthropogenic assets such as cities and towns. There is therefore a smaller decrease associated with the production of this good compared to biodiversity, for example, in the Agro-industrial Scenario. Cultural goods increase with a restoration of native prairie in the Naturalized Scenario. Cultural goods are highly dependent on ecosystem services such as primary production, pollination, water supply, aesthetics, spiritual and traditional use and recreation. The ability of ecosystem services to provide cultural goods decreases in the Agro-industrial Scenario and increases in the Naturalized Scenario, demonstrating a direct relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Future options have a high value of production in southern Alberta, as all assets can be considered to produce some degree of future options. However, since natural assets were usually given a higher importance ranking in terms of producing the good, expanding anthropogenic assets decreases future options in the Agro-industrial Scenario. Conversely, future options are increased in the Naturalized Scenario. Future options are highly dependent on all ecosystem services. The ability of ecosystem services to provide future options goods decreases strongly in the Agro-industrial Scenario and increases highly in the Naturalized Scenario. There is a strong direct relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

Non-market recreational opportunities are highly dependent on all natural assets and some anthropogenic assets such as cities and towns, recreational sites and reservoirs. The small footprint of these compared with natural assets, however, causes non-market recreational opportunities to decrease in the Agro-industrial Scenario. Along with biodiversity, non-market recreation increases by the highest margin with the restoration of native assets in the Naturalized Scenario. This good is highly dependent on several ecosystem services: gas, climate, disturbance and water regulation; biological control; primary production; water supply; aesthetics; spiritual and traditional use; and recreation. The ability of ecosystem services to provide non-market recreational opportunities decreases in the Agro-industrial Scenario and increases in the Naturalized Scenario. There is a direct relationship between the production of the good from the asset and the ability of ecosystem services to provide the good.

4.4 Asset Condition and EGS

Purpose

There is a direct, although not always linear, relationship between the condition of natural assets and the type, quantity and quality of services they provide. The following sections address the research question: *explain and summarize the relationship between the condition of the natural assets and the quantity and quality of services they provide.*

Methods

In the past, little analysis has been carried out related to asset condition over the entire southern Alberta study area. Earlier work utilizing ALCES® provided a very broad overview of the potential impact of the anthropogenic footprint in the region on vegetation assets. However, this was essentially non-spatial and is only one measure of asset condition. Additional analysis is required before it will be possible to quantitatively assess landscape conditions (refer to Section 5, Gap Analysis) and the implications to ecosystem goods and services. Therefore, only a qualitative analysis of how changes in the condition of assets may affect ecosystem services is presented.

4.4.1 *Asset Condition*

Natural asset conditions may be described in terms of composition, connectivity and configuration. All influence different ecosystem functions, processes and services at varying scales. Accordingly, the appropriate scale for condition assessment is dependent upon the process under investigation. In some cases, it is appropriate to report condition metrics at the scale of the entire region, while in others, a finer scale such as the natural region, sub region or other planning unit is more relevant. However, even at the broad regional scale, spatially explicit analysis is required to properly understand both the condition of assets and their influence on services.

Condition is not simply related to vigour and species composition but also to spatial arrangements, even at the broadest of scales. The spatial condition of assets makes a difference. The same amount of assets grouped together or scattered in small fragmented patches provide different levels of service. At the regional scale, patch size, connectivity and configuration have very important ecological implications. There are "indispensable" (Forman, 1995) patterns of asset arrangement that provide ecosystem services that cannot be replicated and need to be considered if the full range of ecosystem services in the region is to be retained. These include:

- The maintenance of large (>10000 ha) patches of natural endemic vegetation;
- Broad well-vegetated riparian corridors;
- Landscape connectivity with corridors and stepping-stones across altered landscapes; and,
- Outliers of natural vegetation scattered throughout highly disturbed landscapes.

The metrics of asset condition are discussed below in Table 4-3.

Table 4-3: Metrics of Asset Condition

Condition Component	Measurable Parameter
Asset Composition	Species Richness and Diversity Amount and proportional representation of: • Natural assets • Anthropogenic assets
Natural Asset Connectivity	Patch Size Contagion of natural assets Linear disturbance density km/km^2
Natural Asset Configuration	Boundaries and Edges • Anthropogenic edge length and density km/km2 Patch arrangement • Number of natural asset types within 1 km2 moving window • Contagion

Asset Composition

Composition of the asset refers to the amount and diversity of habitat types, and greatly influences many ecosystem services. The amount and proportional representation of natural and anthropogenic assets in southern Alberta is an important measure of landscape condition. Amount of habitat is the single most important biodiversity consideration (Fahrig 2002).

Natural Asset Connectivity

Asset connectivity is a measure of the spatial contiguity in a corridor or matrix (mosaic of patches). Analyzing natural asset connectivity involves examining patch size distribution (native prairie and forest assets), contagion of natural assets and linear disturbance density (km/km^2).

Patch Size

Maintenance of large patches of natural vegetation in the landscape is important for a number of reasons, including:

- Habitat to sustain populations of patch interior species;
- Core habitat and escape cover for large home range vertebrates; and,
- Microhabitat proximity for multi-habitat species.

It is important to maintain the distribution of patch sizes that includes both large and small patches within the range of natural variability. Generally speaking, large patches provide large ecological benefits, and small patches provide small supplemental benefits. Large patches are able to offer a quantity and quality of ecosystem services (e.g., disturbance regulation) that no other asset condition can provide.

Thresholds and guidelines for patch size are often quoted in the conservation literature, and are dependent on the target species in question. Kennedy et al. (2003) reviewed 1458 papers in scientific and land use planning journals to find specific information on conservation thresholds. It was concluded that a landscape should include sufficiently large intact and well-connected habitat patches to support the most area-sensitive species, species of environmental concern (e.g., rare, threatened, or endangered species) and/or focal species (Kennedy et al. 2003). Species-dependent guidelines for patch sizes can range from 0.0004 ha (for some invertebrates) up to 220 000 ha for wide-ranging mammals such as bears and cougars (Kennedy et al. 2003). Small mammals (e.g., rodents) make use of patches of 1 to 10 ha in size (Kennedy et al. 2003).

Contagion of Natural Assets

Contagion describes the degree to which assets are clumped or dispersed across the region. This metric quantifies the number of adjacencies between grid cells of the same asset in order to assess the aggregation of that asset. High values of contagion describe a highly dispersed landscape with high spatial variety (e.g., a forest landscape interspersed with small patches of other cover types such as streams or wetlands, versus an agricultural landscape dominated by a cereal crop). High spatial diversity (high contagion) can provide important habitat for those species with life history requirements for multiple habitats in close proximity. However, high contagion in the landscape can mean more edge, which can increase predation, invasive species establishment and spread, and more barriers to species movement. Land managers should try to retain typical levels of contagion in the landscape as a prudent way of retaining associated services such as habitat and refugia.

Linear Disturbance Density

Linear disturbance density is another measure of asset connectivity or landscape fragmentation. Linear disturbances can be deterrents or barriers to species movement, and can therefore fragment populations and make them more susceptible to stochastic events. Linear disturbance analysis includes assessment of vehicular roads as well as all linear disturbances (trails, railways, seismic lines, pipelines and transmission lines).

Natural Asset Configuration

Spatial configuration refers to the arrangement and juxtaposition of patches within natural assets and affects ecosystem services, species use and biodiversity. Important aspects of configuration include the amount of edge and number of natural asset types.

Boundaries and Edges

The length and density of edges are measures of the type and predominance of boundaries in a landscape. This influences species movement and disturbance flows (fire, wind etc.) as well as the types of species utilizing the area. Fewer bird species are often reported in exterior edges of patches. While edge species do play important roles, they tend to be generalists that tolerate frequent disturbance. Edge habitats also often favour the invasion of non-native species such as weeds or cowbirds, which may displace other species. In general, landscape managers do not manage for edge. Rather, they manage to maintain the amount of large patch interiors, which are inversely proportional to edge.

Patch Arrangement

Patch arrangement affects species use of natural asset patches. Different arrangements and patch adjacencies may lead to the creation of convergence points of habitat types. These locations may be of particular importance to certain species that require multi-habitats and a diversity of adjacent resources.

4.4.2 *Potential Implications to Goods and Ecosystem Services from Changes in Asset Condition*

Table 4-4 describes the potential impacts of changes in asset condition. The analysis is qualitative and is intended to assess the trend and magnitude in the provision of ecosystem services, assuming a continued decline in the condition of natural assets in southern Alberta. The assessment draws upon the evaluation of the relationships between ecosystem services, assets and goods conducted as part of this project.

With the exception of gas regulation and climate regulation (where the effects of change in asset condition are difficult to evaluate), the provision of all other ecosystem services in southern Alberta is predicted to decline in the long term. The exception to this trend is food production and the production of raw materials that are expected to increase in the short to mid-term but decline in the long term. The magnitude of this effect is predicted to be high for the services of disturbance regulation, water regulation, biological control, pollination, habitat/refugia, water supply, food production, raw materials, genetic resources, aesthetic, spiritual/traditional and recreation.

The assessment is theoretical and requires further modelling with real data and importance coefficients to verify these predictions. Additional understanding of the relationships between natural asset condition and provision of ecosystem services is also required.

Table 4-4: Potential Implications to Ecosystem Services Resulting From a Change in Asset Condition

Service	Trend (Up, Down, Unknown)	Magnitude (Low, Moderate, High)	Description of Impact
Regulating Services			
Gas Regulation	Unknown	Low	Minor reduction in the regulation of the chemical composition of the atmosphere and oceans. Extremely difficult to quantify regional cause/effects.
Climate Regulation	Unknown	Moderate	Minor reduction in regulation of global temperature, precipitation, and other climate processes at global or local levels. Extremely difficult to quantify regional cause/effects.
Disturbance Regulation	Down	High	Reduction in dampening of environmental fluctuations and disturbances. Storm protection, flood control, drought recovery will be reduced. May have significant negative impacts on forestry, agriculture and recreation.
Water Regulation	Down	High	Role of land cover in regulating runoff and river discharge may be reduced Drainage and irrigation will be negatively affected. Urban flood-prone areas will be affected and infrastructure costs could rise. Recreation and fisheries negatively impacted.
Erosion Control and Sediment Retention	Down	Moderate	Soil loss by wind or runoff will be increased; storage of silt in lakes or wetlands will be increased reducing effectiveness and increasing maintenance costs; Water quality will be reduced as increased chemicals and nutrients are transported in higher volumes of sediment.
Waste Treatment	Down	Moderate	Recovery and breakdown of nutrients and hazardous compounds will be reduced as natural asset condition declines. Riparian buffers will have reduced effectiveness and water quality will be reduced.
Biological Control	Down	High	A decline in the regulation of pest populations and disease is expected. Major impacts may be expected to agriculture and forestry.
Supporting Services			
Soil Formation	Down	Moderate	Soil formation processes are altered as diversity of soil biota and rooting levels are reduced. The accumulation of organic material may be reduced.
Primary Production	Down	Moderate	Long-term primary production will be reduced due to a loss in soil formation and reduction in rooting zone diversity. e.g. simplified vegetation diversity taking advantage of fewer rooting zones. Negative impacts for carbon sequestration.

Table 4-4 cont'd: Potential Implications to Services of Change in Asset Condition

Service	Trend (Up, Down, Unknown)	Magnitude (Low, Moderate, High)	Description of Impact
Nutrient Cycling	Down	Moderate	Cycling and acquisition of nutrients may be altered as soil and organic loss increases due to changes in land cover. Imported nutrients added to systems may have large impacts on aquatic resources as the buffering capacity of ecosystems is reduced.
Pollination	Down	High	Movement of native floral pollinators will be affected by changes in land cover. Increased pesticide and chemical use negatively affects bee populations and large changes in populations are already noted. The value of honeybee pollination in Canada is estimated at one billion dollars annually and multi-million dollar losses may occur, as colonies are lost.
Habitat/refugia	Down	High	Habitat for resident and transient populations will be lost and native species will be replaced. Traditional lifestyles will be affected and recreation and tourism opportunities will be lost. Biodiversity will be reduced.
Provisioning Services			
Water Supply	Down	High	Storage and retention of water by watersheds, reservoirs, and aquifers may be reduced as agricultural and impervious surfaces cover types expand and increase runoff. Agriculture, urban areas and industry (including the energy sector) may be greatly affected by reductions in water supply.
Food Production	Up (short term) Down (long term)	High Moderate	Production of crops and livestock may be increased in the short term but the ability of the land to sustainably produce food in the long term will be reduced as greater amounts of inputs are required to adjust for losses in soil fertility. Livestock production will be threatened as high protein drought resistant native fescue grasslands are reduced. Game and fisheries will be reduced due to loss of habitat quantity and quality.
Raw Materials	Up (short term) Down (long term)	High High	Fibre (lumber and pulp) production may be reduced due to increased disturbance (fire and insects). There may be short-term gains due to "pulse" cutting. Production of non-renewable fuels, and geological materials (aggregates, minerals) are likely to increase in the short to midterm.

Table 4-4 cont'd: Potential Implications to Services of Change in Asset Condition

Service	Trend (Up, Down, Unknown)	Magnitude (Low, Moderate, High)	Description of Impact
Genetic Resources	Down	High	Sources of unique biological materials and products will be irrevocably lost. The range of genetic resources will be reduced, as native biodiversity is lost.
Cultural and Aesthetic Services			
Aesthetic	Down	High	Enjoyment of functioning ecological systems will be reduced as landscapes are transformed. Most Albertans will feel the non-market value of the losses. Increased forestry operations have and will continue to significantly reduce the scenic quality of southern Alberta. An aesthetic resource of global importance will be significantly impacted. Prairie landscapes will be impacted by oil and gas exploration and production. Tourism will be affected.
Spiritual and Traditional Use	Down	High	Traditional uses for aboriginal and non-aboriginal populations will continue to be lost. Spiritual sites and religious activities will be affected directly and indirectly as their context changes. Cultural disillusionment may increase with associated societal costs.
Science and Education	Down	Moderate	Use of natural areas for scientific and educational enhancement may expand as public knowledge of natural systems increases. However, the resources on which the education is based will be reduced. Opportunities for "benchmarking" of natural systems will be lost to scientists and researchers.
Recreation	Down	High	Opportunities for rest, refreshment, and recreation will be reduced forest and grassland ecosystems are impacted by forestry and other land uses. Eco-tourism may see a decline due to failure to meet international expectations.

4.4.3 *Modeling Effects of Changes to Asset Condition*

To create a model that would take asset condition into account, an additional coefficient can be added into the equations for the index of service provision and the index of good production (refer to Section 4.3). This coefficient would rate the condition of the asset on a scale of 0 to 1, based on a number of pre-defined criteria (e.g., fragmentation, native vegetation, etc.).

The equation for the provision of services would then look like this:

Provision of Service 1 in southern Alberta =

$$\frac{(A_1 \times S_{A1} \times C_{A1}) + (A_2 \times S_{A2} \times C_{A1}) + \ldots + (A_{35} \times S_{A35} \times C_{A1})}{200}$$

Where,

A_x = % Asset x in southern Alberta

S_{AX} = Importance of Asset x to providing Service 1

C_{AX} = Condition rating for Asset 1 (between 0 and 1)

And the equation for the production of goods directly from assets:

Provision of Good 1 in southern Alberta =

$$\frac{(A_1 \times G_{A1} \times I_{A1G1} \times C_{A1}) + (A_2 \times G_{A2} \times I_{A2G1} \times C_{A1}) + \ldots + (A_{35} \times G_{A35} \times I_{A35G1} \times C_{A1})}{300}$$

Where,

A_x = % Asset x in southern Alberta

G_{AX} = Importance of Asset x to providing Good 1

I_{AXG1} = Societal/economic importance coefficient for rating the importance of Good 1 produced by Asset x (between 0 and 1)

C_{AX} = Condition rating for Asset 1 (between 0 and 1)

Since the third index, the ability of ecosystem services to support good production, uses the results from the index of service provision, no additional coefficients are needed.

4.5 Overall Ranking of the Importance of Ecosystem Services

Purpose

In addition to considering the individual values of ecosystem services to the maintenance of assets or the production of goods in southern Alberta, a combined overall ranking of each service was considered in relation to the following four variables:

- Importance of the service to the production of goods;
- Importance of the service to the maintenance of assets;
- Relative importance at the margin (the impact of a small change in status of a service on the production of a good or maintenance of an asset); and,
- Manageability (the ability to manage the asset to ensure the delivery of the service).

This analysis differs from that completed in Section 4.1 and Section 4.2 in that it considers the importance of the service within each natural and anthropogenic asset and then ranks each ecosystem service considering the importance of all four variables combined.

Methods

The methodology for this evaluation of overall importance followed that of the Ecosystem Services Project (Ecosystem Services Project, n.d.). In addition to these variables, a final evaluation was undertaken to assess the degree of knowledge of a specific ecosystem service in a particular asset. This evaluation was not considered as part of the overall evaluation but should be used to identify priorities for further investigation and study.

Specific methods employed for each variable are discussed in each of the sections that follow (4.5.1 to 4.5.4). The result of this analysis is the production of 20 summary tables for each ecosystem service that are presented in the Appendices. Each is a tabulation by asset of the value of that particular ecosystem service considering the four variables above. A discussion follows on the evaluation by each variable (Sections 4.5.1 to 4.5.4). Section 4.5.5 discusses the overall ranking of the importance of ecosystem services in southern Alberta.

Tables 4-5 through 4-10 have employed a colour gradient to help illustrate the relative difference in importance of individual ecosystem services. The colour gradient is determined by the cell value in the third column for each table. The range in values is between 1 and 3 for Tables 4-5 through 4-9, while Table 4-10 uses a range between 0 and 3. The selected colour values are the same as those used in Appendices 9-2 to 9-31 and also the spatial maps under preparation by Alberta Environment. It is important for the reader to understand that this analysis of importance is largely based on professional judgement and that the importance of each service is relative to the other 19 services. As the reader will note, the assessment shows that the deviation among individual services is generally quite small.

4.5.1 *Importance of Ecosystem Services to the Production of Goods*

Purpose

This analysis assesses the importance of the individual service to the production of goods in each natural and anthropogenic asset (see Column B in Appendices 9-7 to 9-26).

Methods

The importance of each ecosystem service to the production of goods was discussed previously in Section 4.2. In order to assess the importance of each of the 20 ecosystem services to the production of goods in each asset, additional analysis was required. This was completed by using the analysis of Appendix 9-4 in conjunction with Appendix 9-27 that shows the occurrence of the production of goods in each asset (yes/no only). This assumes an equal value for the production of each good in each asset, as no economic production data were available.

A number of intermediate tables were then produced to calculate the values in Column B (Importance of service to the production of goods) of Appendices 9-7 to 9-26. This column (for each service) is the product of a spreadsheet that calculates a "basket of goods" for each asset shown. The basket of goods is then ranked for each good's importance with respect to the service being analyzed. This approach was taken to enable the value of a service to the production of goods to be represented in a table driven by assets and not goods.

The EGS Assessment used categories of low/moderate/high to rank services in various tables, and divided the rankings into thirds; therefore the highest third will be analysed in this section.

Findings

Table 4-5 shows the ranking of the importance of ecosystem services to the production of goods. The values in Table 4-5 through Table 4-9 represent the average value of the importance to maintenance of assets, production of goods, importance at the margin and manageability. The following discussion describes the top six ecosystem services that are of greatest importance to the production of goods in southern Alberta. Four of the six are regulating services and include: climate regulation; water regulation; disturbance regulation; and gas regulation. The supporting service of primary production is of great importance to the production of goods in Southern Alberta while the provisioning service of water supply rounds out the top six.

Table 4-5: Importance of Ecosystem Services to the Production of Goods

Rank	Ecosystem Services	Importance of service to the production of goods
1	Water supply	
1	Climate regulation	
1	Primary production	
1	Water regulation	
5	Disturbance regulation	
6	Gas regulation	
6	Biological control	
8	Pollination	
8	Spiritual and traditional use	
9	Raw materials	
10	Erosion control and sediment retention	
10	Science and education	
12	Recreation	
13	Genetic resources	
14	Habitat/Refugia	
14	Waste treatment	
16	Nutrient cycling	
16	Soil formation	
16	Food production	
16	Aesthetic	

Water Supply

Most goods produced in southern Alberta have a moderate to high reliance on a stable water supply. Agricultural assets rely on water for sustenance, and anthropogenic assets such as cities, industry, and utilities require large amounts of water.

Climate Regulation

The impact of altered temperature and precipitation levels on the production of goods is ranked as moderate for most of the assets in southern Alberta. The result is a high ranking for this service with respect to the production of goods (see Table 4-5). There are a large number of goods produced in southern Alberta that are sensitive to the impacts of climate (e.g. agriculture, forestry, subsistence, tourism, and aesthetics).

Primary Production

Most goods in southern Alberta are linked back to primary production in some way. For each asset listed in Appendix 9-27 there are a large number of goods that rely on primary production. Examples include: agriculture, forestry, subsistence, tourism, and aesthetics. While some goods may not be viewed as directly linked to primary

Table 4-5: Importance of Ecosystem Services to the Production of Goods

Rank	Ecosystem Services	Importance of service to the production of goods
1	Water supply	**1.9**
1	Climate regulation	**1.9**
1	Primary production	**1.9**
1	Water regulation	**1.9**
5	Disturbance regulation	**1.8**
6	Gas regulation	**1.7**
6	Biological control	**1.7**
8	Pollination	**1.6**
8	Spiritual and traditional use	**1.6**
9	Raw materials	**1.5**
10	Erosion control and sediment retention	**1.4**
10	Science and education	**1.4**
12	Recreation	**1.3**
13	Genetic resources	**1.2**
14	Habitat/Refugia	**1.1**
14	Waste treatment	**1.1**
16	Nutrient cycling	**1.0**
16	Soil formation	**1.0**
16	Food production	**1.0**
16	Aesthetic	**1.0**

Water Supply

Most goods produced in southern Alberta have a moderate to high reliance on a stable water supply. Agricultural assets rely on water for sustenance, and anthropogenic assets such as cities, industry, and utilities require large amounts of water.

Climate Regulation

The impact of altered temperature and precipitation levels on the production of goods is ranked as moderate for most of the assets in southern Alberta. The result is a high ranking for this service with respect to the production of goods (see Table 4-5). There are a large number of goods produced in southern Alberta that are sensitive to the impacts of climate (e.g. agriculture, forestry, subsistence, tourism, and aesthetics).

Primary Production

Most goods in southern Alberta are linked back to primary production in some way. For each asset listed in Appendix 9-27 there are a large number of goods that rely on primary production. Examples include: agriculture, forestry, subsistence, tourism, and aesthetics. While some goods may not be viewed as directly linked to primary production (tourist services and aesthetics) they depend upon intact vegetation communities.

Water Regulation

Many goods produced in southern Alberta have a moderate to high reliance on water regulation. Many agricultural assets rely on overland water supply, while native prairie assets depend on direct rainfall. Anthropogenic assets do not rely as heavily on water regulation as they do on water supply because the regulation function is often an engineered solution.

Disturbance Regulation

The impact of extreme weather events on the production of goods is ranked as moderate for most of the assets in southern Alberta. The result is a high ranking for this service with respect to the production of goods (see Table 4-5). There are a large number of goods produced in southern Alberta that are sensitive to the impacts of extreme weather (e.g. agriculture, forestry, subsistence, tourism, and aesthetics).

Gas Regulation

This service is considered important to southern Alberta due to the importance of native prairie in the sequestration and release of carbon to the atmosphere.

Raw Materials

It might be expected that this provisioning service would be highly ranked in terms of production of goods. Analysis shows that it is not for when the goods produced by raw materials are distributed across all assets, there is a relatively low number of goods for each asset. This results in low rankings for many rows (e.g. prairie grasses). Because no relative valuation of goods (e.g. $ value) was used in this EGS Assessment, a small number of (very important) goods such as livestock for each asset results in a low overall rank for this provisioning service.

4.5.2 *Importance of Ecosystem Services to the Maintenance of Assets*

Purpose

This analysis assesses the importance of each ecosystem service to the maintenance of each natural and anthropogenic asset.

Methods

The scores for each service for the importance to the maintenance of assets are shown in column C of Appendices 9-27 to 9-26. This column represents the average rank of each service across all assets in southern Alberta. For example, one component of the average is the impact of erosion control on fescue grasslands.

Findings

Table 4-6 shows the ranked importance of ecosystem services to the maintenance of assets. The most important services with respect to maintaining assets are all in the categories of regulating and supporting services. These services are of key importance to the maintenance and support of other services and assets in southern Alberta.

Table 4-6: Importance of Ecosystem Services to the Maintenance of Assets

Rank	Ecosystem Services	Importance of service to the maintenance of assets
1	Erosion control and sediment retention	
1	Waste treatment	
3	Climate regulation	
3	Nutrient cycling	
3	Biological control	
3	Disturbance regulation	
3	Water regulation	
8	Primary production	
9	Water supply	
9	Aesthetic	
9	Soil formation	
9	Gas regulation	
13	Pollination	
13	Science and education	
15	Spiritual and traditional use	
15	Recreation	
17	Raw materials	
18	Habitat/Refugia	
19	Food production	
20	Genetic resources	

The following is a discussion of the top six ecosystem services that are of greatest importance to the maintenance of assets (natural and anthropogenic). Five of the top six are regulating services and include: erosion control; waste treatment; disturbance regulation; climate regulation; and biological control. The final ecosystem service of greatest importance to the maintenance of assets is the supporting service of nutrient cycling.

Erosion Control and Sediment Retention

This service is ranked as highly important for most biotic assets due to the potential impact of erosion on primary production and soil formation. The biotic assets that are maintained by this service include: prairie grasses, riparian zones, forests, crops and aquatic assets. This service was ranked as moderately important for several

Findings

Table 4-6 shows the ranked importance of ecosystem services to the maintenance of assets. The most important services with respect to maintaining assets are all in the categories of regulating and supporting services. These services are of key importance to the maintenance and support of other services and assets in southern Alberta.

Table 4-6: Importance of Ecosystem Services to the Maintenance of Assets

Rank	Ecosystem Services	Importance of service to the maintenance of assets
1	Erosion control and sediment retention	[illegible]
1	Waste treatment	[illegible]
3	Climate regulation	[illegible]
3	Nutrient cycling	[illegible]
3	Biological control	[illegible]
3	Disturbance regulation	[illegible]
3	Water regulation	[illegible]
8	Primary production	[illegible]
9	Water supply	[illegible]
9	Aesthetic	[illegible]
9	Soil formation	[illegible]
9	Gas regulation	[illegible]
13	Pollination	2.1
13	Science and education	2.1
15	Spiritual and traditional use	2.0
15	Recreation	2.0
17	Raw materials	1.9
18	Habitat/Refugia	1.8
19	Food production	1.6
20	Genetic resources	1.5

The following is a discussion of the top six ecosystem services that are of greatest importance to the maintenance of assets (natural and anthropogenic). Five of the top six are regulating services and include: erosion control; waste treatment; disturbance regulation; climate regulation; and biological control. The final ecosystem service of greatest importance to the maintenance of assets is the supporting service of nutrient cycling.

Erosion Control and Sediment Retention

This service is ranked as highly important for most biotic assets due to the potential impact of erosion on primary production and soil formation. The biotic assets that are maintained by this service include: prairie grasses, riparian zones, forests, crops and aquatic assets. This service was ranked as moderately important for several anthropogenic assets due to the possibility of damage to the built environment, for example: campgrounds, human settlements, and oil field infrastructure.

Waste Treatment

The service of waste treatment was deemed of high importance for most biotic assets due to sensitivity to anthropogenic or human waste products, for example: prairie grasses, riparian zones, forests, crops and aquatic assets. It was also deemed of high importance to several anthropogenic assets, including: human settlements, feedlots, and campgrounds.

Climate Regulation

Climate regulation is considered to be highly important to the maintenance of almost all biotic assets in southern Alberta. The avoidance of climate extremes (altered precipitation and temperature regime) was seen to be of great importance to: native prairie grasses, riparian zones, forests, crops, aquatic assets, bare soil, and ice. Climate regulation was also seen as a moderately important service for protecting anthropogenic assets. This importance was lower than for natural assets due to the human ability to "protect" assets, for example, hardened surfaces in settlements. Anthropogenic assets of moderate importance include human settlements, where extreme financial and loss of life is possible. This service did not impact some assets to the degree that disturbance regulation did, simply due to the lower intensity of disturbances to: roads, well sites, pipelines, and feedlots.

Nutrient Cycling

Nutrient cycling is deemed to be of high importance to the maintenance of almost all biotic assets in southern Alberta. This is because of the importance of primary production to the region and the connection between nutrient cycling and primary production. Biotic assets that are highly dependent on this service for maintenance include: prairie grasses, riparian zones, forests, crops, and aquatic assets.

Biological Control

Biological control is deemed of high importance for the maintenance of almost all biotic assets in southern Alberta. This is due to the potential impact of pests and diseases on the southern Alberta landscape (e.g. grasshoppers, West Nile virus, pine beetle) and the importance of maintaining balanced predator prey relationships. The importance of the service was high for assets including: native prairie grasses, riparian zones, forests, crops and aquatic assets. It was also considered of high importance to anthropogenic assets, including human settlements, feedlots, and campgrounds.

Disturbance Regulation

Disturbance regulation was deemed of high importance for the maintenance of almost all biotic assets in southern Alberta. The avoidance of extreme weather events (storms, floods, tornados) was seen to be of great importance to: native prairie grasses, riparian zones, forests, crops and aquatic assets. Disturbance regulation was also seen as a highly important service or moderately important service for protecting anthropogenic assets. The importance was lower than for natural assets due to the human ability to "protect" assets, for example, hardened surfaces in settlements or rip-rap on river banks. Anthropogenic assets of high importance include human settlements, where extreme financial and loss of life is possible. Anthropogenic assets of moderate importance include roads, well sites, pipelines, and feedlots.

4.5.3 *Importance of Ecosystem Services at the Margin*

Purpose

This analysis assesses the sensitivity of ecosystem services in relation to their capability to produce goods or maintain natural and anthropogenic assets. In other words, what is the impact of a small change in status of a service on the production of a good or maintenance of an asset?

Methods

The analysis was undertaken in two parts. Two input tables were created in order to assess the importance of ecosystem services at the margin. Appendix 9-28 shows the sensitivity at the margin in relation to the production of goods and Appendix 9-29 the sensitivity at the margin in relation to maintenance of assets.

The scores for each service for the importance at the margin were taken from the fifth column of Appendices 9-7 to 9-26. This column represents the average rank of each service across all assets in southern Alberta. For example, one component of the average is the impact of disturbance regulation at the margin for fescue grasslands.

Services that are important at the margin include those where a small change in the integrity of the service may result in a large change in the production of goods or to the maintenance of the asset. The assessment of this relationship is complex to assess, and it is recommended that the findings in this report be further verified with additional scientific study.

Table 4-7 shows the overall results of the importance of ecosystem services at the margin. It was found that primarily the regulating services (and one supporting service) tend to have the most importance at the margin. This is likely because regulating and supporting services typically act on other services. This can have an amplifying effect, in that a small change in the support of another service can have a large impact on goods and assets in southern Alberta.

The following is a discussion with respect to the five most important ecosystem services at the margin. These include four regulating services (disturbance regulation, biological control, climate regulation and waste treatment) and the supporting service of nutrient cycling.

Each of these services was also found in the previous list of most important services to the maintenance of assets. The only service in the previous list not found here was erosion control. While an important service for the maintenance function, it was not seen to have an amplifying effect or high importance at the margin.

Table 4-7: Importance of Ecosystem Services at the Margin

Rank	Ecosystem Services	Importance of service at the margin
1	Disturbance regulation	[illegible]
2	Biological control	[illegible]
3	Climate regulation	2.2
4	Nutrient cycling	2.1
5	Waste treatment	2.0
6	Soil formation	1.9
7	Water supply	1.8
7	Erosion control and sediment retention	1.8
9	Water regulation	1.7
10	Pollination	1.6
11	Raw materials	1.5
12	Primary production	1.4
13	Habitat/Refugia	1.3
13	Gas regulation	1.3
15	Food production	1.2
16	Recreation	1.1
17	Science and education	1.0
17	Genetic resources	1.0
17	Aesthetic	1.0
17	Spiritual and traditional use	1.0

Disturbance Regulation

Disturbance regulation was deemed to be highly important at the margin relative to almost all biotic assets in southern Alberta. A small change in the ability to prevent extreme storms, floods, or droughts could result in a relatively large impact to the region. The avoidance of extreme weather events (storms, floods, tornados) was seen to be of great importance to: native prairie grasses, riparian zones, forests, crops and aquatic assets. Disturbance regulation was also seen as a highly important service or moderately important service for protecting anthropogenic assets. The importance was lower than for natural assets due to the human ability to "protect" assets, for example, hardened surfaces in settlements or rip-rap on river banks. Human settlements where extreme financial and loss of life is possible were considered highly important. Anthropogenic assets of moderate importance include: roads, well sites, pipelines and other linear facilities, industrial sites, and feedlots.

Biological Control

Biological control is considered to be of high importance at the margin for almost all biotic assets in southern Alberta. This is because of the potential impact of pests and diseases and the importance of maintaining predator prey relationships. It is likely that if

Table 4-7: Importance of Ecosystem Services at the Margin

Rank	Ecosystem Services	Importance of service at the margin
1	Disturbance regulation	
2	Biological control	
3	Climate regulation	
4	Nutrient cycling	
5	Waste treatment	
6	Soil formation	
7	Water supply	
7	Erosion control and sediment retention	
9	Water regulation	
10	Pollination	
11	Raw materials	
12	Primary production	
13	Habitat/Refugia	
13	Gas regulation	
15	Food production	
16	Recreation	
17	Science and education	
17	Genetic resources	
17	Aesthetic	
17	Spiritual and traditional use	

Disturbance Regulation

Disturbance regulation was deemed to be highly important at the margin relative to almost all biotic assets in southern Alberta. A small change in the ability to prevent extreme storms, floods, or droughts could result in a relatively large impact to the region. The avoidance of extreme weather events (storms, floods, tornados) was seen to be of great importance to: native prairie grasses, riparian zones, forests, crops and aquatic assets. Disturbance regulation was also seen as a highly important service or moderately important service for protecting anthropogenic assets. The importance was lower than for natural assets due to the human ability to "protect" assets, for example, hardened surfaces in settlements or rip-rap on river banks. Human settlements where extreme financial and loss of life is possible were considered highly important. Anthropogenic assets of moderate importance include: roads, well sites, pipelines and other linear facilities, industrial sites, and feedlots.

Biological Control

Biological control is considered to be of high importance at the margin for almost all biotic assets in southern Alberta. This is because of the potential impact of pests and diseases and the importance of maintaining predator prey relationships. It is likely that if a slight reduction in the pest control function allows pests to establish a small foothold, then a major outbreak could occur. The importance of the service was high for assets including prairie grasses, and spruce and pine forests. It was also deemed important to anthropogenic assets, including human settlements, feedlots, and campgrounds.

Climate Regulation

Climate regulation was judged to be of high importance at the margin for almost all biotic assets in southern Alberta. A small change in the efficacy of this service could result in a large impact to natural and anthropogenic assets. The avoidance of climate extremes (altered precipitation and temperature regimes) was seen to be of great importance to prairie grasses, riparian zones, forests, crops, and wetlands. Climate regulation was also seen as a moderately important service for protecting anthropogenic assets. The importance was lower than for natural assets due to the human ability to "protect" assets. Anthropogenic assets of moderate importance include human settlements, roads, well sites, campgrounds and pipelines and other linear facilities.

Nutrient Cycling

Nutrient cycling is regarded as having high importance at the margin to almost all biotic assets in southern Alberta. This is because of the importance of primary production to the region and the connection between nutrient cycling and primary production. Biotic assets that are highly sensitive at the margin include: crops and aquatic assets. Those moderately sensitive include: prairie grasses, forests, and human habitation. Because of the complexity of this service, further analysis and investigation is warranted.

Waste Treatment

The service of waste treatment was deemed of high importance at the margin for most biotic assets due to sensitivity to anthropogenic or human waste products. It was deemed that a small change in natural waste treatment function could result in the accumulation of waste products and have a moderate or large impact on assets (e.g. a small amount of bacteria in drinking water can have a significant impact on humans). Assets that could be highly impacted include: crops (due to the economic impacts of changes to yield). Moderate impacts could be seen on: native prairie grasses, riparian zone, forests, and human settlements.

4.5.4 *Ability to Manage the Assets to Provide Services*

Purpose

This analysis assesses the ability to manage the asset to provide the service. This includes both natural and anthropogenic assets.

Methods

The assessment of the ability for humans to manage individual ecosystem services within assets (manageability) was a highly subjective exercise. The information presented in Appendix 9-30 represents the collective professional opinion of the project team and may require further refinement and input by relevant professionals and resource managers. This assessment took into account the ability for humans to manage assets at a reasonable cost whilst generating a significant improvement to ecosystem services, and thus goods. It should be noted that low scoring services (e.g. pollination or climate regulation) may reflect a data gap and could suggest a need for additional primary research.

The assessment of the manageability of ecosystem services to provide assets was based upon the following three criteria:

- Of low ability to manage or not applicable (1)
- Moderate ability to manage (2)
- High ability to manage (3)

The ability to manage assets to provide services was assessed for each ecosystem service at each asset type. The value given to the availability of data at each asset type (1, 2, or 3) was then averaged in the final spreadsheet. The result of the average score determines the final ranking that is represented by the number appearing in Table 4-8.

It is important to note that the ability to manage an asset is considered separately from the importance of an asset to any given good or ecosystem services. It refers to our ability to understand, manipulate and manage an asset. A low ability to manage an asset could be construed as more important than an asset that is readily managed. This particular analysis focuses on our ability to manage the asset irregardless of its importance to the provision of ecological goods and services.

There is also merit in distinguishing the ability to manage renewable and non-renewable goods produced from natural assets. Renewable goods have the potential for long-term sustainable production. In contrast, non-renewable goods, such as coal and petroleum, provided a limited, although very much important service. Management of the asset however, does not only consider management solely in order to maximize the production of goods. The production of non-renewable goods often has more significant environmental and social impacts than does the production of renewable goods. Each should be managed in a way to conserve the resource while limiting the impacts associated with their production.

Findings

Table 4-8 shows the ranking of ecosystem services in consideration of our ability to manage each of the 36 assets to either enhance or maintain the 20 ecosystem services.

The following discussion considers the five ecosystem services that are thought to be most reactive to the management of assets in southern Alberta. Three out of the top five are cultural uses and include: science and education; aesthetic; and recreation. It is not all that surprising that the most reactive services are cultural services. In addition, the regulating services of erosion control and sediment retention and nutrient cycling comprise the remaining ecosystem services that are considered to be most responsive to the management of assets.

Table 4-8: Ability to Manage Ecosystem Services

Rank	Ecosystem Services	Ability to manage asset for service
1	Science and education	
2	Erosion control and sediment retention	
2	Aesthetic	
4	Recreation	
5	Nutrient cycling	
6	Water supply	
6	Primary production	
6	Gas regulation	
6	Habitat/Refugia	
6	Food production	
11	Genetic resources	
11	Waste treatment	
11	Raw materials	
14	Water regulation	
15	Spiritual and traditional use	
16	Soil formation	
16	Biological control	
18	Disturbance regulation	
18	Pollination	
20	Climate regulation	

Science and Education

The cultural service of science and education that uses natural areas for educational enhancement was determined to be the most responsive service by a significant margin. In terms of the 36 asset types that were assessed, it was determined that there is a high capacity for humans to manage the assets to provide for science and education on 34 of them. While natural assets such as native grasslands, forests, lakes, rivers and wetlands are obvious in terms of their ability to provide an educational benefit, anthropogenic assets provide a very similar opportunity.

Erosion Control and Sediment Retention

Erosion control and sediment retention is the only regulating service that was deemed to have significant opportunity in terms of the manageability of assets to provide for the service. Given the hardships associated with erosion the 1930s, erosion control and sediment retention have received high priority in southern Alberta. The result is a vast array of engineering adaptations to reduce erosion and control sediment in constructed environments. On agricultural lands, new practices of zero and minimum tillage have improved the retention of topsoil in arid environments. The result is that 15 of the 36 assets were considered to be highly manageable for this service.

Table 4-8: Ability to Manage Ecosystem Services

Rank	Ecosystem Services	Ability to manage asset for service
1	Science and education	[illegible]
2	Erosion control and sediment retention	[illegible]
2	Aesthetic	[illegible]
4	Recreation	[illegible]
5	Nutrient cycling	[illegible]
6	Water supply	2.0
6	Primary production	2.0
6	Gas regulation	2.0
6	Habitat/Refugia	2.0
6	Food production	2.0
11	Genetic resources	1.9
11	Waste treatment	1.9
11	Raw materials	1.9
14	Water regulation	1.8
15	Spiritual and traditional use	1.7
16	Soil formation	1.6
16	Biological control	1.6
18	Disturbance regulation	1.5
18	Pollination	1.5
20	Climate regulation	1.4

Science and Education

The cultural service of science and education that uses natural areas for educational enhancement was determined to be the most responsive service by a significant margin. In terms of the 36 asset types that were assessed, it was determined that there is a high capacity for humans to manage the assets to provide for science and education on 34 of them. While natural assets such as native grasslands, forests, lakes, rivers and wetlands are obvious in terms of their ability to provide an educational benefit, anthropogenic assets provide a very similar opportunity.

Erosion Control and Sediment Retention

Erosion control and sediment retention is the only regulating service that was deemed to have significant opportunity in terms of the manageability of assets to provide for the service. Given the hardships associated with erosion the 1930s, erosion control and sediment retention have received high priority in southern Alberta. The result is a vast array of engineering adaptations to reduce erosion and control sediment in constructed environments. On agricultural lands, new practices of zero and minimum tillage have improved the retention of topsoil in arid environments. The result is that 15 of the 36 assets were considered to be highly manageable for this service.

Aesthetic

The ability to provide for the cultural service of aesthetics tied with recreation, erosion control and sediment retention, and raw materials for the second most responsive ecosystem service. Humans have proven their ability to intervene to provide for those items of greatest value to them, and aesthetics is certainly one of those given high priority. This is especially true in natural areas of high recreational importance such as forest and aquatic assets and anthropogenic assets such as cities and towns, campgrounds and ski hills, and reservoirs. Fifteen of the 36 assets were viewed to have significant potential for managing to provide for the service of aesthetics.

Recreation

The ability to manage assets to provide for the cultural service of recreation is quite similar to that of aesthetic. It should however be noted that our ability to manage assets to provide for recreation is thought to be high on 21 of 36 asset types including native prairie, forests and aquatic landscapes; and in residential areas, campgrounds and reservoirs. While the number of assets where there is a high ability to manage for recreational activities is greater than for aesthetic, there is also a low ability to manage a greater number of assets, such as agricultural.

Nutrient Cycling

Nutrient cycling was one of the top six services considered to be highly manageable largely due to its importance to the production of agricultural crops and maintenance of native prairie and forest assets in southern Alberta.

4.5.5 *Overall Ranking of Ecosystem Services*

Purpose

This analysis determines an overall ranking of the importance of ecosystem services in southern Alberta, considering each of the four aforementioned variables (importance to production of goods, importance to maintenance of assets, importance at the margin and manageability).

Methods

The overall ranking of each ecosystem service is an aggregation of each of the preceding tables: importance of service to the production of goods; importance of the service to the maintenance of assets; importance of service at the margin; and the ability to manage the asset to provide the service. The weightings of each column (B, C, D, E,) were assumed to be of equal importance. The columns were then summed having used a value of 1, 2 or 3 to represent low, moderate, or high importance for each criterion with a minimum possible value of 4 and a maximum possible value of 12 for each asset relative to each service. Given this range, it was then possible to create a series of new ranges (4-6 = low; 7-9 = moderate, 10-12 = high) for each asset type and reassigned a new value of 1, 2 or 3 to be consistent with preceding columns. As a final step, the values of each of the 36 asset types were averaged to create an overall ranking for each ecosystem service, which is the number represented in Table 4-9.

The range (from a low of 1.2 to a high of 2.1) for the overall ranking of ecosystem services is not large and reflects the importance of all ecosystem services to providing a sustainable future for southern Alberta.

The following is a brief discussion with respect to the six highest overall ranked ecosystem services. These include four regulating services (disturbance regulation, water regulation, erosion control and sediment retention and biological control), one supporting service (nutrient cycling) and one provisioning service (water supply).

It should be noted that the overall ranking of the importance of ecosystem services in southern Alberta is an un-weighted average of the importance of the four variables previously described: importance of the service to the production of goods, importance of the service to the maintenance of assets, relative importance at the margin and manageability. The overall ranking of the importance of ecosystem services as described in Table 4-9 considers the contribution of each variable to be equal when in fact this may not be the case. Some ecosystem services may have a greater importance to the production of goods; others may be more important toward the maintenance of assets. Also the value of the importance at the margin and manageability may also have a greater or lesser value.

Table 4-9 therefore should be interpreted as a first step to understanding the importance of ecosystem services and to invoke further discussion as to what factors influence the importance of a given service. Future analyses of the overall ranking of the importance of ecosystem services to southern Alberta could consider the following questions:

- Should the weighting of each variable be changed? If so, how?;
- Should the importance of ecosystem services be considered separately for natural versus anthropogenic assets?;
- Should the production of goods in each asset consider their economic value? The current assessment only looks at production on a presence/absence basis in each asset type;
- Should the importance at the margin or manageability be considered separately?; and
- Should our knowledge of ecosystem services (considered separately in this assessment) be incorporated into this analysis?

Table 4-9: Overall Ranking of the Importance of Ecosystem Services in Southern Alberta

Rank	Ecosystem Services	Overall ranking
1	Biological control	2.1
1	Erosion control and sediment retention	2.1
1	Water supply	2.1
4	Water regulation	2.0
4	Nutrient cycling	2.0
4	Disturbance regulation	2.0
4	Climate regulation	2.0
4	Waste treatment	2.0
9	Primary production	1.9
10	Gas regulation	1.8
11	Soil formation	1.7
11	Science and education	1.7
13	Pollination	1.6
13	Recreation	1.6
13	Raw materials	1.6
16	Aesthetic	1.5
16	Habitat/Refugia	1.5
16	Spiritual and traditional use	1.5
19	Food production	1.3
20	Genetic resources	1.3

The following is a summary of the importance of the top six ecosystem services in southern Alberta.

Biological Control

Biological control is an important regulating service for the control or regulation of pest populations and the regulation of trophic relationships. Successful biological control operates at the population level, not the individual level, and requires a detailed understanding of species interactions across a number of trophic levels. Biological control was considered to be of greatest importance in areas where goods are harvested. A total of seven forest and agricultural landscapes denote the high importance of this service to southern Alberta. Contemporary concerns, such as West Nile virus and the Mountain Pine Beetle, factored heavily into the high importance value attributed to this service.

Erosion Control and Sediment Retention

Erosion control and sediment retention is a regulating service important for the retention of soil within an ecosystem. It tied for tnird ranked ecosystem service. Like the preceding services, erosion and sediment control was seen to be of at least moderate importance in nearly all asset types. Erosion and sediment control was considered

Table 4-9: Overall Ranking of the Importance of Ecosystem Services in Southern Alberta

Rank	Ecosystem Services	Overall ranking
1	Biological control	
1	Erosion control and sediment retention	
1	Water supply	
4	Water regulation	
4	Nutrient cycling	
4	Disturbance regulation	
4	Climate regulation	
4	Waste treatment	
9	Primary production	
10	Gas regulation	
11	Soil formation	
11	Science and education	
13	Pollination	
13	Recreation	
13	Raw materials	
16	Aesthetic	
16	Habitat/Refugia	
16	Spiritual and traditional use	
19	Food production	
20	Genetic resources	

The following is a summary of the importance of the top six ecosystem services in southern Alberta.

Biological Control

Biological control is an important regulating service for the control or regulation of pest populations and the regulation of trophic relationships. Successful biological control operates at the population level, not the individual level, and requires a detailed understanding of species interactions across a number of trophic levels. Biological control was considered to be of greatest importance in areas where goods are harvested. A total of seven forest and agricultural landscapes denote the high importance of this service to southern Alberta. Contemporary concerns, such as West Nile virus and the Mountain Pine Beetle, factored heavily into the high importance value attributed to this service.

Erosion Control and Sediment Retention

Erosion control and sediment retention is a regulating service important for the retention of soil within an ecosystem. It tied for third ranked ecosystem service. Like the preceding services, erosion and sediment control was seen to be of at least moderate importance in nearly all asset types. Erosion and sediment control was considered highly important to the functioning of six asset types including forests, cereal crops and in riparian zones.

Water Supply

Water supply is a provisioning service for the storage and retention of both surface and subsurface water by watersheds. It was the only provisioning service to make the top six important services. The importance of watersheds is not surprising given the predominance of semi-arid landscapes in southern Alberta. Overall, water supply was seen to be of high importance to fourteen asset types, the most of any service. Water supply was most important to anthropogenic assets rather than natural assets, including nearly all agricultural landscapes, rural/agricultural residential, cities and towns, industrial sites, reservoirs and canals.

Water Regulation

Water regulation is a regulating service of great importance to southern Alberta and particularly for areas of irrigated crops where as much as 65% of rainfall is captured, held and released to the landscape. Water regulation will gain greater importance in coming years due to the coupled impact of climate change and pending drought.

Nutrient Cycling

Nutrient cycling (or biogeochemical cycling) is a supporting service and is defined as the storage, internal cycling, processing and acquisition of nutrients such as carbon, nitrogen, phosphorus, and sulphur. Nutrient cycling tied with disturbance regulation for the most important ecosystem service of the twenty services assessed. This is largely because nutrient cycling is a fundamental process occurring in an ecosystem with dramatic effects on individuals, populations and communities.

In our assessment of nutrient cycling, this process was considered significant in nearly all asset types, and of critical importance to fourteen asset types including forests, agricultural lands, aquatic environments and other anthropogenic assets such as cities and towns and feedlots.

Disturbance Regulation

Disturbance regulation is a regulating service defined as the dampening of environmental fluctuations and disturbances such as floods and fires. It received a ranking equal to nutrient cycling. Disturbance regulation was seen to be of critical importance for seven asset types, including forests, cereal crops, and cities and towns.

4.6 Knowledge of Ecosystem Services in Southern Alberta

Purpose

This analysis assesses knowledge of the function and process of ecosystem services in southern Alberta. It is intended to identify those services where we have a good level of understanding and those where more research and investigation is needed. This analysis could be supplemented at a later date with an additional assessment of data availability (both spatial and non-spatial) for each asset.

Methods

The assessment of our knowledge of ecosystem services in southern Alberta was a highly subjective exercise. It is considered to be preliminary and represents the professional opinions of the project team and will likely require further refinement and input by relevant professionals. The assessment was completed independently of the overall ranking of ecosystem services. Rather, the information is presented to give the reader an understanding of how well we understand these ecosystem services relative to their overall importance. The usefulness of this data is that a highly important ecosystem service with a low score for availability of data could suggest a need for additional primary research in this subject area.

The assessment of knowledge with regard to each ecosystem service by asset was undertaken using the following four rankings (see Appendix 9-31):

- Not Applicable (0)
- Understanding/ Availability (1)
- Moderate Understanding/ Availability (2)
- High Understanding/ Availability (3)

The value given to the availability of data at each asset type (0, 1, 2, or 3) was then averaged with all “Not Applicable” data ranges removed from the formula.

Findings

The overall ranking of ecosystem services with respect to knowledge of function and process is shown in Table 4-10. The seven highest ranked services include the regulating services of water regulation, and erosion control and sediment retention; the supporting services of habitat/refugia and primary production; the provisioning services of raw materials and food production; and the cultural service provided by recreation.

The following is a discussion of our knowledge of ecosystem services in southern Alberta. Of note is that there is a gap between our understanding of these services and our willingness to manage the service to provide the asset. This assessment considers our understanding, not our willingness or ability to manage assets to provide ecosystem services.

Table 4-10: Ranking With Respect to Knowledge of Ecosystem Services in Southern Alberta

Rank	Ecosystem Services	Knowledge of Ecosystem Services
1	Recreation	[redacted]
1	Habitat/Refugia	[redacted]
3	Water regulation	[redacted]
3	Erosion control and sediment retention	[redacted]
5	Raw materials	[redacted]
6	Food production	[redacted]
6	Primary production	[redacted]
8	Soil formation	[redacted]
9	Waste treatment	[redacted]
10	Aesthetic	[redacted]
10	Nutrient cycling	[redacted]
10	Science and education	[redacted]
13	Disturbance regulation	[redacted]
13	Climate regulation	[redacted]
15	Spiritual and traditional use	[redacted]
15	Water supply	[redacted]
17	Biological control	[redacted]
18	Gas regulation	[redacted]
18	Pollination	[redacted]
20	Genetic resources	[redacted]

Recreation

Recreation and habitat/refugia tied for first ranking with respect our knowledge of the function and process of ecosystem services, scoring a maximum value of 3.0. Our knowledge of the service of recreation was considered high for 31 of 36 asset types. There was little or no applicability of recreational uses to five anthropogenic assets including well sites, pipelines, transmission and seismic lines, feedlots, mines and pits and industrial sites. A score of 3.0 does not suggest that we know everything there is to know about this service at each asset type, but rather, our understanding of these services in southern Alberta is high relative to other services.

Habitat/Refugia

Habitat/refugia tied with recreation in terms of our current understanding of the ecosystem service across the various asset types considered. Current knowledge of habitat and species of terrestrial populations across southern Alberta is high, representing the level of effort recently expended on inventories and the identification of remaining areas of native habitat. Our knowledge of habitat and refugia in aquatic environments is not considered as high as those of terrestrial systems.

Table 4-10: Ranking With Respect to Knowledge of Ecosystem Services in Southern Alberta

Rank	Ecosystem Services	Knowledge of Ecosystem Services
1	Recreation	[illegible]
1	Habitat/Refugia	[illegible]
3	Water regulation	[illegible]
3	Erosion control and sediment retention	[illegible]
5	Raw materials	[illegible]
6	Food production	[illegible]
6	Primary production	[illegible]
8	Soil formation	[illegible]
9	Waste treatment	[illegible]
10	Aesthetic	[illegible]
10	Nutrient cycling	[illegible]
10	Science and education	[illegible]
13	Disturbance regulation	2.1
13	Climate regulation	2.1
15	Spiritual and traditional use	2.0
15	Water supply	2.0
17	Biological control	1.9
18	Gas regulation	1.7
18	Pollination	1.7
20	Genetic resources	1.6

Recreation

Recreation and habitat/refugia tied for first ranking with respect our knowledge of the function and process of ecosystem services, scoring a maximum value of 3.0. Our knowledge of the service of recreation was considered high for 31 of 36 asset types. There was little or no applicability of recreational uses to five anthropogenic assets including well sites, pipelines, transmission and seismic lines, feedlots, mines and pits and industrial sites. A score of 3.0 does not suggest that we know everything there is to know about this service at each asset type, but rather, our understanding of these services in southern Alberta is high relative to other services.

Habitat/Refugia

Habitat/refugia tied with recreation in terms of our current understanding of the ecosystem service across the various asset types considered. Current knowledge of habitat and species of terrestrial populations across southern Alberta is high, representing the level of effort recently expended on inventories and the identification of remaining areas of native habitat. Our knowledge of habitat and refugia in aquatic environments is not considered as high as those of terrestrial systems.

Water Regulation

Our level of understanding of water regulation in southern Alberta is high, scoring a ranking of 2.9. The understanding of water regulation was ranked high in 31 assets and moderate in the remaining five (all native prairie landscapes). The importance of trees, such as poplar and cottonwoods, to absorb and retain water in riparian areas is well known as our knowledge of the importance of forest cover on the eastern slopes for flood control. Our understanding of water regulation is believed to be higher than that of water supply that ranks considerably lower largely due to the limited understanding of regional groundwater resources in southern Alberta.

Erosion Control and Sediment Retention

As noted in Section 4.5.5, our ability to manage assets to provide ecosystem services is high for the regulating service of erosion control and sediment retention. As a result of this capability, our understanding of the process and function of erosion control and sediment retention is high and tied with water regulation.

Raw Materials

Alberta and southern Alberta are regions where significant production of raw materials (e.g. lumber, aggregates, oil and gas) from the natural landscape occurs, and it is therefore no surprise that raw materials (a provisioning service) ranks fifth in regard to knowledge and understanding of the service. Our assessment suggests that there is a high level of understanding of raw materials occurring in the forest and agricultural asset areas, but relatively less in native prairie landscapes and aquatic landscapes. Overall, we determined that raw materials are applicable to 30 of 36 asset types and that there is a good understanding of raw materials in 23 asset types.

Food Production

Food production (a provisioning service) is also very important to southern Alberta and it stands to reason that this service would rank highly in terms of knowledge and understanding. In contrast to the preceding services, food production occurs in fewer asset types and was applicable to only 18 of 36 asset types assessed. Native prairie landscapes are important for cattle grazing and has therefore provided for a good level of understanding. Our understanding of food production on agricultural landscapes is thought to be excellent and recognizes the role of southern Alberta as a significant exporter of agricultural products.

Primary Production

Our knowledge of the role of primary production, a supporting service, is also thought to be quite high, tying with food production for sixth highest ranking. It is not altogether surprising that these ecosystem services ranked very closely. While primary production is a supporting service and food production a provisioning service, these services are intrinsically linked given that food production relies on primary production. This is not the only interrelationship existing between services, though it is one of the most evident.

Genetic Resources

The provisioning service provided by genetic resources was the lowest ranked service with respect to our current levels of understanding, and is also discussed briefly.

The low ranking for the provisioning service provided by genetic resources is that we still have a great deal to learn about the services provided by nature. It is perhaps true that we will never fully understand the genetic resources provided by natural assets despite significant efforts to do so. Future option values provided by nature for medicinal purposes as an example are poorly understood in the global context and this is thought to be no different in the southern Alberta context. Genetic resources are thought to be particularly poorly understood with respect to natural landscapes while they are quite well known in agricultural landscapes for both crop and livestock production.

5.0 Gap Analysis and Future Directions

This section of the EGS Assessment identifies information gaps regarding ecosystem services in southern Alberta and how they should be addressed in future. The gaps are prioritized as follows:

- High– considered to be urgent and should be undertaken in the next six months;
- Moderate – considered to be less urgent and should be undertaken in the next year; and,
- Low – considered to be important but can only be undertaken after the other gaps are addressed in the next 1 to 2 years.

5.1 High Priority

Gap #1: There is a need to understand the value of goods produced in southern Alberta in greater detail.

Background

This EGS Assessment uses an aggregation of industry sectors to develop our analyses of goods produced in southern Alberta. Not all goods will be recognized this way. The economic value of the goods or industry sectors has not been assessed.

Proposed Solution

In an effort to better represent the benefits of ecosystem services in southern Alberta, less aggregation may be desirable. The study should be more specific with respect to which goods are being evaluated. Further, goods will need to be traced back to determine the full extent of the inputs originating in southern Alberta. Undertaking an assessment based upon land use similar to the Australian Ecosystem Services Project may be a better way to account for goods rather than by industry sector. This approach may simplify the analysis by comparing groups of assets and goods (land uses) to services, resulting in more detailed (but perhaps less broad) analysis.

Gap #2: The EGS Assessment considered all evaluation criteria to be weighted equal.

Background

This project did not assess the relative value of each asset when compared to other assets or the relative value of goods when compared to others. The Australian Ecosystem Services Project addressed this by grouping goods and assets into a land use category (e.g. Dairying). The land use was then valued in terms of dollars of goods produced by areal extent.

A further concern occurs with respect to the equal weighting of each different analysis conducted in this work, e.g. the importance of a service to the production of goods. At present, each of the four variables considered in this EGS Assessment were considered to be of equal importance with respect to the overall importance of a service. It is likely that some adjustments will be required. For example, the ability to manage assets with respect to the services they provide may not be as significant as the importance of a service to the maintenance of assets.

Proposed Solution

A primary task of future work should be to create a framework to determine relative importance of assets, goods and also the four criteria used to determine overall ranking. Once complete this work should be revised to reflect these new weightings.

Gap #3: There is a need to conduct more in-depth research into the interrelationships between ecosystem services and natural assets to complement the results of the EGS Assessment.

Background

The size and duration of this contract did not permit the project team sufficient time to conduct in depth research with respect to the role of each service and each asset in the southern Alberta context.

Proposed Solution

Future initiatives should be constructed to allow for in depth research regarding the role of ecosystem services in the production of goods and maintenance of assets. This work should also include identifying the interrelationships that exist between the 20 ecosystem services that were largely considered independent of each other in this assessment. In fact they are likely highly interrelated. It will also be important to have a comprehensive understanding of the value of ecological components at various scales. It is suggested that an expert workshop be held to convene a group of knowledgeable experts in EGS to enhance the work of this initial assessment.

Gap #4: There is a need for more in-depth spatial analysis of asset condition.

Background

The current project focuses on the potential for a given asset to provide services and goods, without a detailed examination of how the condition of that asset affects the provision and quality of ecosystem services and goods. There are further asset condition analyses that should be done to better assess the quality of an asset. Discussion of the importance of these condition metrics is found in Section 4.4.

Proposed Solution

In order to accurately assess the condition of a natural asset, two scales of analyses are recommended: regional/sub-regional evaluations (broad-scale) and field studies (fine-scale). While the focus of the proposed work is at the broad scale, additional fine scale surveys are required, particularly in the grasslands. Table 5-1 lists suggested analyses and measurable parameters.

Table 5-1: Asset Condition Analyses

Scale of Analysis	Suggested Analysis	Measurable Parameter
Regional / Sub-Regional	Asset composition	Amount and proportional representation of: • Natural assets • Anthropogenic assets
	Natural asset connectivity	Patch Size of natural assets Contagion of natural assets Linear disturbance density km/km^2
	Natural asset configuration	Boundaries and Edges • Anthropogenic edge length and density km/km^2
		Patch arrangement • Number of natural asset types within 1 km^2 moving window
Field Studies	Natural asset composition	Grassland vegetation inventory

Asset Composition

Asset composition should be analyzed in terms of amount and proportional representation of natural and anthropogenic assets.

Natural Asset Connectivity

Analyzing natural asset connectivity involves examining patch size distribution (native prairie and forest assets), contagion of natural assets and linear disturbance density (km/km^2).

Patch Size of Natural Assets

It is suggested that contiguous patches of natural vegetation be classified into the following size classes:

- >10,000 ha (nationally important)
- 1000 to 10,000 ha (regionally important)
- 250 to 1000 ha
- 50 to 250 ha
- 2 to 10 ha

Contagion of Natural Assets

Measures of contagion should be assessed for natural regions and sub-regions. The measure is not useful at the regional level.

Linear Disturbance Density

Linear disturbance density can be calculated in southern Alberta by converting map files to raster and reporting on mean km/km^2 within a 1 km^2-moving window. This can be reported by natural sub-regions or other relevant planning units.

Natural Asset Configuration

An important aspect of configuration that should be examined includes the amount of edge (anthropogenic edge length and density (km/km^2) should be calculated in addition to the number of natural asset types within a 1 km^2 moving window.

Natural Asset Configuration – Field Surveys

Field surveys need to be conducted to support regional dataset evaluations and provide fine-scale data for priority sites. A useful field study that should be continued and expanded is the Grassland Vegetation Inventory. These inventories must be kept current in order to feed back into the regional dataset evaluations.

5.2 Medium Priority

Gap #5: There is a need for public review and comment with regard to the importance of ecosystem goods and services in southern Alberta.

Background

The results of this ecosystem services assessment represent the professional opinion of the project team and should be considered preliminary. The intent of this assessment is to prepare a baseline evaluation and approach that can be taken to wider public consultation.

Proposed Solution

While it is recognized that there are risks with taking information to the public too early in the process, the opposite is also true. It is suggested that Alberta Environment consider the results of this EGS Assessment as an initial platform from which to engage a much wider audience. In doing so, this will create buy-in and will also be able to elicit responses that verify the professional opinion reflected herein. Alternately, arguments may be sufficient to overturn some of the assumptions that were made by the project team resulting in a more accurate and rigorous assessment. Finally, future work will also need to consider how to engage a broad stakeholder group at various geographic scales over issues where consensus may not be possible. The results of public review and comment should lead to policy development with respect to protection of ecosystem services.

Gap #6: There is a need for standardization of methodologies for the assessment of ecosystem goods and services of ecosystem goods and services.

Background

An underlying concern with a project or initiative such as this is the inability to compare methodology and results with other projects. As ecosystem goods and services assessment is still in its infancy, especially in the practical arena where little has been done, the ability to compare and contrast work is extremely limited. While there is ample work being done at the academic level with respect to EGS and its importance, the Ecosystem Services Project in the Goulburn Broken Catchment, Victoria, Austraiia provides the lone case study for our work in southern Alberta. The Ecosystem Services Project has a significantly larger budget and is a much larger initiative, now underway for many years. As a result, a set of standardized valuation methods/framework should be produced so that the EGS Assessment work in southern Alberta can be compared with similar areas.

Proposed Solution

There are a number of initiatives underway to standardize approaches to EGS assessments. The World Resources Institute (WRI) is presently drafting a manual to assist EGS practitioners. IUCN has an online database of some 200 EGS case studies. Alberta Environment may want to consider harmonizing further evaluation of ecosystem goods and services in conjunction with these standard approaches. Additional initiatives, such as the EcoValue Project at the Gund School of Ecological Economics at the University of Vermont that provide an interactive decision support system for assessing and reporting the economic value of ecosystem goods and services in a geographic context are also useful opportunities for exchange of EGS assessment methodologies.

5.3 Low Priority

Gap #7: There is a need to coordinate the valuation of ecosystem goods and services with tools and instruments used in policy development to protect them.

Background

The EGS Assessment focused on attempting to understand the relationships between ecosystem services, assets and goods produced in southern Alberta. There was no attempt made at this stage to consider the value of the services, assets and goods. Other EGS assessments in Alberta are underway to identify tools, policy incentives and other mechanisms to assist in the protection of ecosystem services, goods and assets.

Proposed Solution

It is important that EGS initiatives in Alberta encompass a dual approach. The first is to develop a technical understanding of the interrelationships between ecosystem services, assets and goods and assess their value and importance. The second is the application of policy tools and instruments to develop policies related to EGS and their protection. Together these two approaches should be linked to broader policy development and decision making processes currently underway for land use planning and resource allocation in southern Alberta.

6.0 Summary of Major Findings

The results of this assessment of the importance of ecosystem goods and services in southern Alberta should be considered as preliminary in nature. The findings await further verification and discussion with key stakeholders and the public. The following section presents a summary of key findings of the EGS Assessment:

- A total of 20 ecosystem services were assessed as to their importance in producing goods or maintaining natural assets in southern Alberta. The ecosystem services were categorized into four types of services: regulating, supporting, provisioning and cultural and aesthetic. The latter group of services are considered important in that they capture a wide variety of non-market benefits associated with the conservation of natural assets.

- A conceptual model of linkages between ecosystem services, assets and goods was developed. The model shows that strong linkages exist between natural assets (native prairie, forest and aquatic assets) and regulating and supporting services. Natural assets, agricultural assets and other anthropogenic assets are also important in regard to provisioning services. Provisioning services (water, food, raw materials and genetic resources) are also important inputs to the production of goods in the primary and secondary sectors of the southern Alberta economy. Cultural services are most important to the production of goods in the tertiary sector of the economy and producing cultural and aesthetic goods.

- The Project team assessed the 20 ecosystem services for their relative importance in southern Alberta using four criteria which include importance to the production of goods, importance to the maintenance of assets, importance at the margin, and manageability. An overall ranking of the importance of ecosystem services in southern Alberta was determined. The results of this assessment conclude that the top six ecosystem services of greatest overall importance to southern Alberta are biological control, erosion control and sediment retention, water supply, water regulation, nutrient cycling and disturbance regulation.

- As noted, the overall ranking of ecosystem services used a series of intermediate assessments (importance of the service to the production of goods, importance of the service to the maintenance of assets, relative importance at the margin, and manageability) that were averaged to provide a score out of 3.0 and then ranked accordingly. The most important services to the production of goods include water supply, climate regulation, primary production and water regulation. Ecosystem services of greatest importance to the maintenance of assets include erosion control and sediment retention, waste treatment, climate regulation, nutrient cycling, biological control, disturbance regulation and water regulation. Ecosystem services of greatest importance at the margin were determined to be disturbance regulation, biological control, climate regulation, nutrient cycling, and waste treatment. Finally, ecosystem services assessed as most manageable include science and education, erosion control and sediment retention, aesthetics, recreation, nutrient cycling and water supply.

- Independent of the overall ranking of ecosystem services, current understanding and knowledge of ecosystem services in the context of southern Alberta were considered. The primary purpose of the assessment is to identify gaps in knowledge and target further EGS initiatives. Knowledge of the function and process of ecosystem services was highest for recreation, habitat/refugia, water regulation, erosion control and sediment retention, raw materials, food production and primary production. Conversely, knowledge of genetic resources, pollination and gas regulation is least understood. This part of the assessment will require revision in consultation with resource managers and EGS specialists.

- A series of linked spreadsheet models was developed to demonstrate that changes to the amount and distribution of natural assets affect the type, quantity, and quality of ecosystem services. In turn, the sustainability of goods produced by ecosystem services is affected. The existing conditions and two hypothetical scenarios (Agro-industrial and Naturalized) were analyzed to assess the impact of expanding anthropogenic assets on the capacity of natural assets to provide ecosystem services to either produce goods or maintain assets. Under the Agro-industrial Scenario there is a decrease in native prairie assets, forest assets, tame pasture, and a corresponding increase in cereal, oilseeds and legumes, specialty crops, forage crops, and other anthropogenic assets. In the Naturalized Scenario there are decreases in agricultural assets, roads and rails, rural/agricultural residential, cities, well sites, pipelines, feedlots, recreation sites, industrial sites, canals and increases in native prairie and forest assets.

- The impact of expanding anthropogenic assets on the provision of services under both scenarios was analyzed. In the Agro-industrial Scenario, anthropogenic assets are increased at the expense of natural assets; in response, the index of service provision in southern Alberta decreases to varying degrees for all ecosystem services. The greatest decreases are seen for the services of biological control, habitat/refugia, genetic resources and spiritual and traditional use. Habitat/refugia also become a net loss under this scenario. Services related to primary production and food production also decrease in this scenario. While agriculture expands, the very ecosystem services that it depends on are reduced (maintenance of soil fertility, nutrient cycling etc). While goods may actually increase under this scenario, it is at the expense of long-term supporting ecosystem services, which must be supplemented by external inputs such as fuel and fertilizer.

- Under the Naturalized Scenario, increasing the proportion of native assets on the landscape causes the services of biological control, habitat/refugia, genetic resources and spiritual and traditional use to show the highest corresponding increases in service provision. The smallest increases are shown with respect to waste treatment and raw materials; two services, primary production and food production actually show a slight decrease under this scenario. This effect can be attributed to the large-scale conversion of arable agriculture, forage and tame pasture back into native prairie assets.

- The impact of expansion of anthropogenic assets on the capacity of ecosystem services to produce goods under the Agro-industrial Scenario showed increases in crop production, agricultural processing, oil and gas refining, and increases in the tertiary service sector (manufacturing, construction, transportation, government etc.). Biodiversity, aesthetic and cultural goods, future options and non-market recreational opportunities all decreased under the Agro-industrial scenario. Under the Naturalized scenario, crop production, agricultural production, oil and gas refining and some service goods (construction, transportation, government) decreased while livestock production, subsistence, tourism, biodiversity, aesthetic and cultural goods, future options and non-market recreational opportunities increased.

- Natural asset conditions can be described in terms of composition, connectivity and configuration. All influence different ecosystem functions, processes and services at varying scales. Changes in the condition of natural assets on both the trend and magnitude with regard to the provision of the service were assessed. With the exception of gas regulation and climate regulation (where the effects of change in asset condition are difficult to evaluate), the provision of all other ecosystem services in southern Alberta is predicted to decline in the long term. The exceptions to this trend are food production and the production of raw materials which are expected to increase in the short to mid-term but decline in the long term. The magnitude of this effect is predicted to be highest for the services of disturbance regulation, water regulation, biological control, pollination, habitat/refugia, water supply, food production, raw materials, genetic resources, aesthetic, spiritual/traditional and recreation. Further modelling with real data and importance coefficients is required to verify these predictions.

- A gap analysis was completed to identify further information needs and future directions for ecosystem goods and services assessment in southern Alberta. Key themes emerging from the gap analysis include: 1) the need for standardized methodologies and approaches to EGS assessment; 2) the need to incorporate economic valuation of market and non-market benefits associated with EGS; 3) the need to review the results of the assessment in a public forum; 4) the need to couple the results of the EGS assessment with spatially explicit modelling and planning to address the issues of what and where to develop; and, 5) the need to link technical EGS assessments and policy tools and instruments for EGS protection into the broader policy development and decision making framework for land-use planning and resource allocation in southern Alberta.

7.0 References

In addition to the references cited in the text, the Phase 1 EGS report contains over 200 references in an annotated bibliography.

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8.0 Glossary of Key Terms

Acronym or Term	Definition
AENV	Alberta Environment
ALCES®	A landscape cumulative effect simulator tool developed in Alberta to help decision-makers and stakeholders explore how land use practices interact with natural processes to change the landscape.
Anthropogenic Assets	Man-made assets that produce a wide variety of goods for human benefit.
Assets	Something useful or valuable.
Contagion	The degree to which assets are clumped or dispersed across a given area.
Commons	Or equivalently a common property resource or public good; a resource that provides services that must be shared by some community of individuals or the public.
Cultural services	Are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.
Contiguity	A measure of the degree of wholeness within a region or of the degree to which polygons are in contact with one another
Discount rate	Used to allow comparisons of benefits and costs experienced at different points in time. It allows conversion of future values into their present-day equivalent.
Ecosystem functions	Refer variously to the habitat, biological or system properties or processes of ecosystems.
Ecosystem goods	Tangible and intangible benefits to human beings derived from ecosystem services.
Ecosystem services	Flow from natural assets (soil, water systems, plants, animals, other living organisms and the atmosphere) to provide us with financial, ecological and cultural benefits. If natural assets are not maintained the benefits from ecosystem services decline. Conversely, if we maintain our natural assets and use them more effectively, we will benefit from greater returns.
EGS	Ecosystem goods and services.

Acronym or Term	Definition
Externality	Occurs when the actions of one individual impose costs or benefits on another individual, who has not agreed to receive those costs or benefits.
Genuine Progress Indicators (GPI)	As a unique sustainability accounting standard, "the GPI Accounts provide concrete, best evidence of the current and historical condition or well-being of our natural, social, human and economic-manufactured capital or assets, as well as identifying emerging liabilities and the distribution of ownership of capital assets in society (i.e. owners' equity, wealth and income distribution) (Anielski, 2001, p. 1).
Goods	Are all things produced in the southern Alberta Landscape that are of value to humans. In this study we emphasise the role of natural assets in the production of goods. However, it is important to also recognise the role of manufactured capital, technology, labour and social institutions in the production of goods.
Gross Domestic Product (GDP)	The market value of all final goods and services produced within a given area (usually a country) in a given period of time. It is also considered the sum of value added at every stage of production of all final goods and services produced within a country in a given period of time.
Importance at the margin	The impact of a small change in a service on the production of a good or the maintenance of natural assets. Example, will a small change in pollination significantly affect crop yields? This criterion was used to assess "input to production" and "maintaining natural assets".
Input to production	Assessment of ecosystem services in this role was based on a combined weighting of the value of goods associated with each land-use/industry and the importance of the ecosystem service in producing those goods. Input to production was assessed using the overall importance, importance at the margin and manageability.
Maintaining natural assets	Assessment of ecosystem services in this role was based on the impact of each land-use/industry on the capacity of natural assets to continue to provide ecosystem services.
Manageability	The capacity to manage the land-use/industry to ensure the ongoing delivery of the service (noting that a low ranking may imply a high priority for further effort). This criteria was used to assess "input to production" and "maintaining natural assets".

Acronym or Term	Definition
Market failure	When the market alone does not result in an efficient provision of some good or service. The provision of a service is said to be efficient when it is impossible to make any individual better off without making someone else worse off. Market failures are typically caused by the presence of externalities.
MES	Market for Ecosystem Service.
Natural assets	Refer to the stock of natural resources from which many ecosystem services and goods are produced.
Natural capital	As opposed to human or manufactured capital, natural capital is the stock of society's environmental assets.
Non-extractive services	Services that do not involve removing biomass from the ecosystem providing the service, for example, water purification services.
Normative economics	Provides recommendations to policy-makers concerning what should happen in some situation and how best to intervene to ensure that it does. By comparison, positive or descriptive economics is the more objective study of what does happen.
Overall importance/ impact	A criterion used to assess the overall importance of the service in relation to the production of goods; and also to assess the impact of the land-use/industry on ecosystem service's capacity to maintain natural assets. See also "input to production" and "maintaining natural assets".
PES	Payment for Ecosystem Services.
Primary sector	Generally involves the changing process of natural resources into primary products. Most products from this sector are considered raw materials for other industries.
Production function (PF)	Is an approach that estimates the contribution an ecosystem service makes to the production of a marketed/ marketable service such as drinking water.
Provisioning services	Are the products people obtain from ecosystems, such as food, fuel, fiber, fresh water, and genetic resources.
Regulating services	Are the benefits people obtain from the regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, regulation of human diseases, and water purification.
SAL Project	Southern Alberta Landscape Project.

Acronym or Term	Definition
Secondary sector (or manufacturing sector)	Includes those economic sectors that create a finished, usable product: manufacturing and construction. This sector of industry generally takes the output of the primary sector and manufactures finished goods or products to a point where they are suitable for use by other businesses, for export, or sale to domestic consumers.
Stochastic	A stochastic process is one whose behaviour is non-deterministic in that a state does not fully determine its next state.
Supporting services	Are those services that are necessary for the production of all other ecosystem services, such as primary production, production of oxygen, and soil formation.
Tertiary sector (or service sector)	This sector includes non-physical products and services such as customer care. The tertiary sector is often involved in distribution logistics and retailing, and industries in this sector do not effect any major changes in physical goods before reselling them to the customer.
Valuation	The process of estimating the willingness of individuals to sacrifice or pay to achieve some goal or outcome.
Willingness-to-pay (or ability to pay)	Is the foundation of the economic theory of value. The idea is, if something is worth having, then it is worth paying for and can be applied to environmental resources like water quality and natural resources like trees. The key assumption is that environmental values are anthropogenic. Whatever people think the environment is worth is what it is worth. Economic methods can be used to attach estimates of willingness to pay to changes in the level of environmental quality and natural resource use.

9.0 Appendices

Appendix 9-1: List of Ecosystem Services, Natural and Anthropogenic Assets and Goods Considered as Part of the EGS Assessment

Ecosystem Services	Natural and Anthropogenic Assets	Goods
Regulating Gas regulation Climate regulation Disturbance regulation Water regulation Erosion control and sediment retention Waste treatment Biological control **Supporting** Soil formation Primary production Nutrient cycling Pollination Habitat/Refugia **Provisioning** Water supply Food production Raw materials Genetic resources **Cultural and aesthetic** Aesthetic Spiritual and traditional Science and education Recreation	**Native Prairie** Needle and thread dry mixed grass Northern wheat dry mixed grass Needle and thread sand grass dry mixed grass Mixed grass Fescue grasslands Rocky mountain and parkland fescue Prairie treed and riparian cottonwood complex Prairie shrub Badlands and thin breaks **Forest** Forest shrub Hardwood forest Mixedwood forest Spruce and fir forest Pine forest **Agricultural** Cereal crops Oilseeds and Legumes Specialty crops Forage crops Tame pasture **Aquatic** Lentic water (still) Lotic water (flowing) Prairie wetlands Forest wetlands **Geologic** Bare soil and rock Ice **Other Anthropogenic** Roads/rails Rural residential/Ag residential City/town Well sites Pipelines/transmission lines/seismic lines Feedlots Recreation-campgrounds and ski hills Mines/pits Industrial sites Reservoirs Canals	**Primary Sector of Industry** Agriculture-crop/vegetable Agriculture-livestock Oil and gas Forestry Mining Subsistence **Secondary Sector of Industry** Agriculture processing Oil and gas refining Other manufacturing **Tertiary Sector of Industry** Construction Transportation and utilities Trade (wholesale/retail) Health and education Tourist services Government and non profit Other services **Cultural and Aesthetic** Biodiversity Aesthetic Cultural Future options Non-market recreational

Appendix 9-2 Relationship between Ecosystem Services and Assets

Ecosystem Services	Description	Examples
Regulating Services		
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	CO2/O2 balance, ozone for UVB protection
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels	GHG regulation, DMS (ocean gas) production affecting cloud formation
Disturbance regulation	Dampening of environmental fluctuations and disturbance	Storm protection, flood control, drought recovery
Water regulation	Role of land cover in regulating runoff and river discharge	Drainage and natural irrigation, medium for transport
Erosion control and sediment retention	Retention of soil within an ecosystem	Prevention of soil loss by wind or runoff; storage of silt in lakes or wetlands; protecting water quality
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds	Biodegradation, anaerobic digestion, detoxification, dilution, protection of water quality
Biological control	Regulation of pest populations and disease	Predator control of prey species, reduction of herbivory by animals
Supportive services		
Soil formation	Soil formation process	Weathering of rock and the accumulation of organic material
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	Nitrogen fixation, N, P and other elemental or nutrient cycles
Pollination	Movement of floral pollinators	Provisioning of pollinators for the reproduction of plant populations.
Habitat/Refugia	Habitat for resident and transient populations	Nurseries, habitat for migratory or resident species
Provisioning services		
Water supply	Storage and retention of water by watersheds (includes surface and subsurface)	Provisioning, storage and retention of water by watersheds, reservoirs, and aquifers
Food production	That portion of gross primary production extractable as food	Production of crops, fish, fodder, game, nuts, fruits.
Raw materials	Natural resource production	Production of lumber, fuels, and geological materials (aggregates, minerals)
Genetic resources	Sources of unique biological materials and products	Medicine, genes for resistance to crop pests, horticultural varieties of plants
Cultural Services		
Aesthetic	Sensory enjoyment of functioning ecological systems	Artistic, photography, enjoyment.
Spiritual and traditional use	Spiritual and historic information	Traditional uses for aboriginal and non-aboriginal populations; spiritual sites and religious activities
Science and education	Use of natural areas for scientific and educational enhancement	Scientific research, science class field trips, increasing public knowledge of natural systems
Recreation	Opportunities for rest, refreshment, and recreation	Eco-tourism, sport fishing, hiking, boating, climbing.

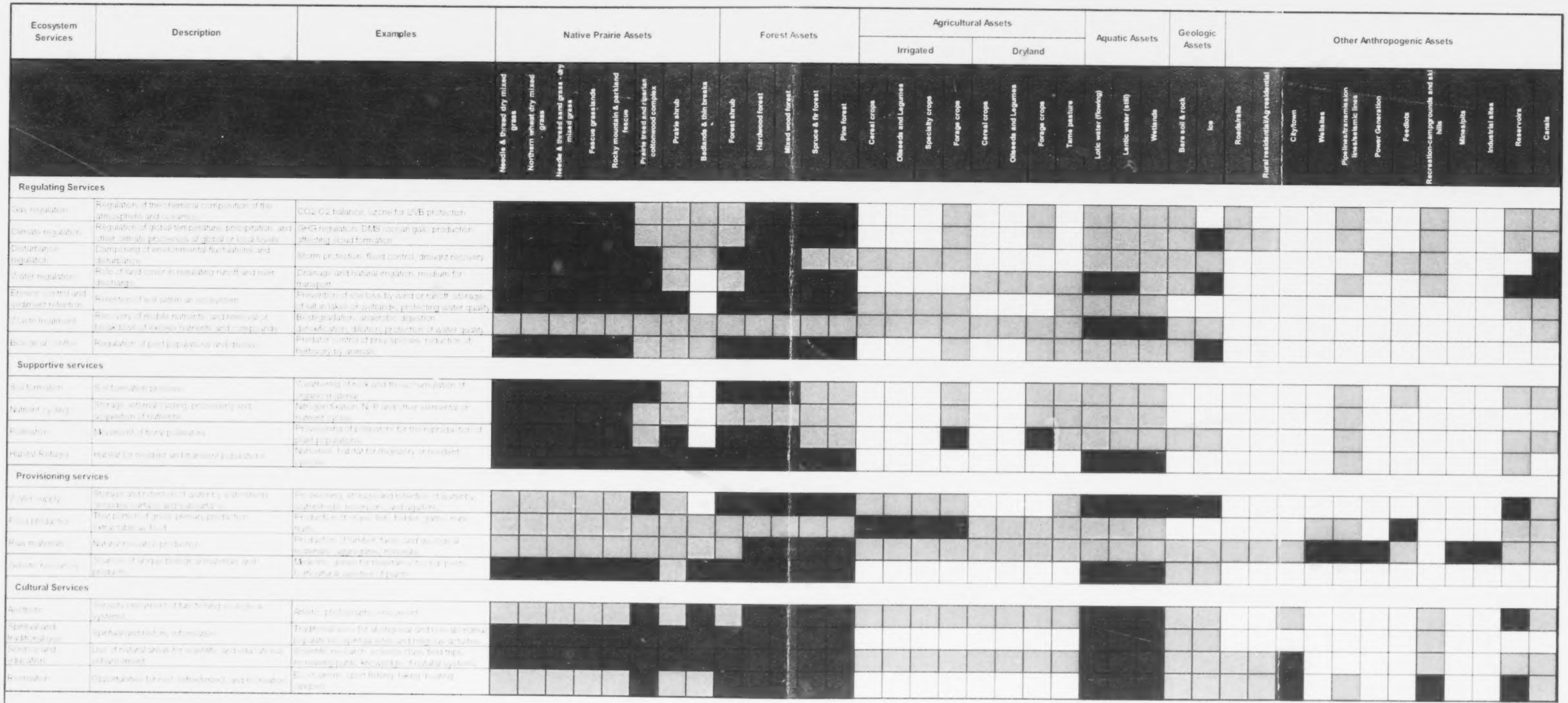
Ecosystem Services	Native Prairie Assets								Forest Assets				
	Needle & thread dry mixed grass	Northern wheat dry mixed grass	Needle & thread sand grass - dry mixed grass	Fescue grasslands	Rocky mountain & parkland fescue	Prairie treed and riparian cottonwood complex	Prairie shrub	Badlands & thin breaks	Forest shrub	Hardwood forest	Mixed wood forest	Spruce & fir forest	Pine forest
Regulating Services													
Gas regulation	■	■	■	■	■	■	■	■	■	■	■	■	■
Climate regulation	■	■	■	■	■	■	■	■	■	■	■	■	■
Disturbance regulation	■	■	■	■	■	■	■	■	■	■	■	■	■
Water regulation	■	■	■	■	■	■	■	□	■	■	■	■	■
Erosion control and sediment retention	■	■	■	■	■	■	■	□	■	■	■	■	■
Waste treatment	■	■	■	■	■	■	■	■	■	■	■	■	■
Biological control	■	■	■	■	■	■	■	■	■	■	■	■	■
Supportive services													
Soil formation	■	■	■	■	■	■	■	□	■	■	■	■	■
Nutrient cycling	■	■	■	■	■	■	■	□	■	■	■	■	■
Pollination	■	■	■	■	■	■	■	□	■	■	■	■	■
Habitat/Refugia	■	■	■	■	■	■	■	■	■	■	■	■	■
Provisioning services													
Water supply	■	■	■	■	■	■	■	□	■	■	■	■	■
Food production	■	■	■	■	■	■	■	■	■	■	■	■	■
Raw materials	■	■	■	■	■	■	■	■	■	■	■	■	■
Genetic resources	■	■	■	■	■	■	■	■	■	■	■	■	■
Cultural Services													
Aesthetic	■	■	■	■	■	■	■	■	■	■	■	■	■
Spiritual and traditional use	■	■	■	■	■	■	■	■	■	■	■	■	■
Science and education	■	■	■	■	■	■	■	■	■	■	■	■	■
Recreation	■	■	■	■	■	■	■	■	■	■	■	■	■

Ecosystem Services	Agricultural Assets								Aquatic Assets			Geologic Assets	
	Irrigated				Dryland								
	Cereal crops	Oilseeds and Legumes	Specialty crops	Forage crops	Cereal crops	Oilseeds and Legumes	Forage crops	Tame pasture	Lotic water (flowing)	Lentic water (still)	Wetlands	Bare soil & rock	Ice
Regulating Services													
Gas regulation	□	□	□	■	□	□	■	□	■	■	■	■	□
Climate regulation	□	□	□	■	□	□	■	□	■	■	■	■	■
Disturbance regulation	■	■	■	■	□	□	□	□	■	■	■	■	■
Water regulation	□	□	□	□	■	■	■	■	■	■	■	■	■
Erosion control and sediment retention	■	■	■	■	□	□	□	■	■	■	■	□	□
Waste treatment	■	■	■	■	■	■	■	■	■	■	■	■	■
Biological control	□	□	□	■	□	□	■	■	■	■	■	■	■
Supportive services													
Soil formation	□	□	□	■	□	□	■	■	■	■	■	□	□
Nutrient cycling	□	□	□	■	□	□	■	■	■	■	■	□	□
Pollination	□	□	□	■	□	□	■	■	■	■	■	■	■
Habitat/Refugia	□	□	□	□	□	□	□	□	■	■	■	□	□
Provisioning services													
Water supply	■	■	■	■	□	□	□	■	■	■	■	■	■
Food production	■	■	■	■	■	■	■	■	■	■	■	□	□
Raw materials	■	■	■	■	■	■	■	■	■	■	■	■	■
Genetic resources	□	□	□	□	□	□	□	□	■	■	■	■	■
Cultural Services													
Aesthetic	■	■	■	■	■	■	■	■	■	■	■	■	■
Spiritual and traditional use	□	□	□	□	□	□	□	□	■	■	■	■	■
Science and education	■	■	■	■	■	■	■	■	■	■	■	■	■
Recreation	□	□	□	□	□	□	□	□	■	■	■	■	■

Ecosystem Services	Other Anthropogenic Assets											
	Roads/rails	Rural residential/Ag residential	City/town	Wellsites	Pipelines/transmission lines/seismic lines	Power Generation	Feedlots	Recreation-campgrounds and ski hills	Mines/pits	Industrial sites	Reservoirs	Canals
Regulating Services												
Gas regulation	■	□	□	□	■	□	□	■	□	□	■	■
Climate regulation	■	■	□	□	■	□	□	■	□	□	■	■
Disturbance regulation	□	□	□	□	□	■	■	■	□	□	□	■
Water regulation	□	□	□	□	■	□	□	■	□	□	■	■
Erosion control and sediment retention	□	□	□	□	□	□	□	□	□	□	■	■
Waste treatment	□	□	□	□	□	□	□	□	□	□	□	■
Biological control	□	□	□	□	□	□	□	□	□	□	□	□
Supportive services												
Soil formation	□	□	□	□	■	□	■	□	□	□	■	■
Nutrient cycling	□	□	□	□	■	□	□	□	□	□	□	□
Pollination	□	□	□	□	■	□	□	□	□	□	■	■
Habitat/Refugia	□	□	□	□	■	□	□	□	□	□	■	□
Provisioning services												
Water supply	□	□	□	□	□	□	□	□	□	□	■	■
Food production	□	□	□	■	■	□	■	□	□	□	■	■
Raw materials	■	■	■	■	■	■	■	□	■	■	■	■
Genetic resources	□	□	□	□	□	□	□	□	□	□	□	□
Cultural Services												
Aesthetic	□	□	■	□	□	□	□	■	□	□	■	■
Spiritual and traditional use	□	□	□	□	□	□	□	■	□	□	□	□
Science and education	■	■	■	□	□	□	□	■	□	□	■	■
Recreation	■	■	■	□	■	□	□	■	□	□	■	■

Positive	■
Somewhat positve	■
Neutral	■
Somewhat Negative	□
Negative	□

Appendix 9-2 Relationship between Ecosystem Services and Assets



Native Prairie Assets
Forest Assets
Agricultural Assets
Irrigated
Dryland
Aquatic Assets
Geologic Assets
Other Anthropogenic Assets
Needle & thread dry mixed grass
Northern wheat dry mixed grass
Needle & thread sand grass - dry mixed grass
Fescue grasslands
Rocky mountain & parkland fescue
Prairie treed and riparian cottonwood complex
Prairie shrub
Badlands & thin breaks
Forest shrub
Hardwood forest
Mixed wood forest
Spruce & fir forest
Pine forest
Cereal crops
Oilseeds and Legumes
Specialty crops
Forage crops
Cereal crops
Oilseeds and Legumes
Forage crops
Tame pasture
Lotic water (flowing)
Lentic water (still)
Wetlands
Bare soil & rock
Ice
Roads/rails
Rural residential/Ag residential
City/town
Wellsites
Pipelines/transmission lines/seismic lines
Power Generation
Feedlots
Recreation-campgrounds and ski hills
Mines/pits
Industrial sites
Reservoirs
Canals

Ecosystem Services	Description	Examples
Regulating Services		
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	CO2/O2 balance, ozone for UVB protection
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels	GHG regulation, DMS (ocean gas) production affecting cloud formation
Disturbance regulation	Dampening of environmental fluctuations and disturbance	Storm protection, flood control, drought recovery
Water regulation	Role of land cover in regulating runoff and river discharge	Drainage and natural irrigation, medium for transport
Erosion control and sediment retention	Retention of soil within an ecosystem	Prevention of soil loss by wind or runoff, storage of silt in lakes or wetlands, protecting water quality
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds	Bio-degradation, anaerobic digestion, detoxification, dilution, protection of water quality
Biological control	Regulation of pest populations and disease	Predator control of prey species, reduction of herbivory by animals
Supportive services		
Soil formation	Soil formation process	Weathering of rock and the accumulation of organic material
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	Nitrogen fixation, N, P and other elemental or nutrient cycles
Pollination	Movement of floral gametes	Provisioning of pollinators for the reproduction of plant populations
Habitat Refugia	Habitat for resident and transient populations	Nurseries, habitat for migratory or resident species
Provisioning services		
Water supply	Storage and retention of water by watersheds, includes surface and aquifers	Provisioning, storage and retention of water by watersheds, reservoirs, and aquifers
Food production	That portion of gross primary production extractable as food	Production of crops, fish, fruit, game, nuts
Raw materials	Natural resource production	Production of lumber, fuels and geological materials, aggregates, minerals
Genetic resources	Sources of unique biological materials and products	Medicine, genes for resistance to plant pests, horticultural varieties of plants
Cultural Services		
Aesthetic	Sensory enjoyment of functioning ecological systems	Artistic, photographic, enjoyment
Spiritual and traditional use	Spiritual and historic information	Traditional uses for aboriginal and non-aboriginal populations, spiritual sites and heritage activities
Science and education	Use of natural areas for scientific and educational enhancement	Scientific research, science class field trips, increasing public knowledge of natural systems
Recreation	Opportunities for rest, refreshment, and recreation	Eco-tourism, sport fishing, hiking, hunting, camping

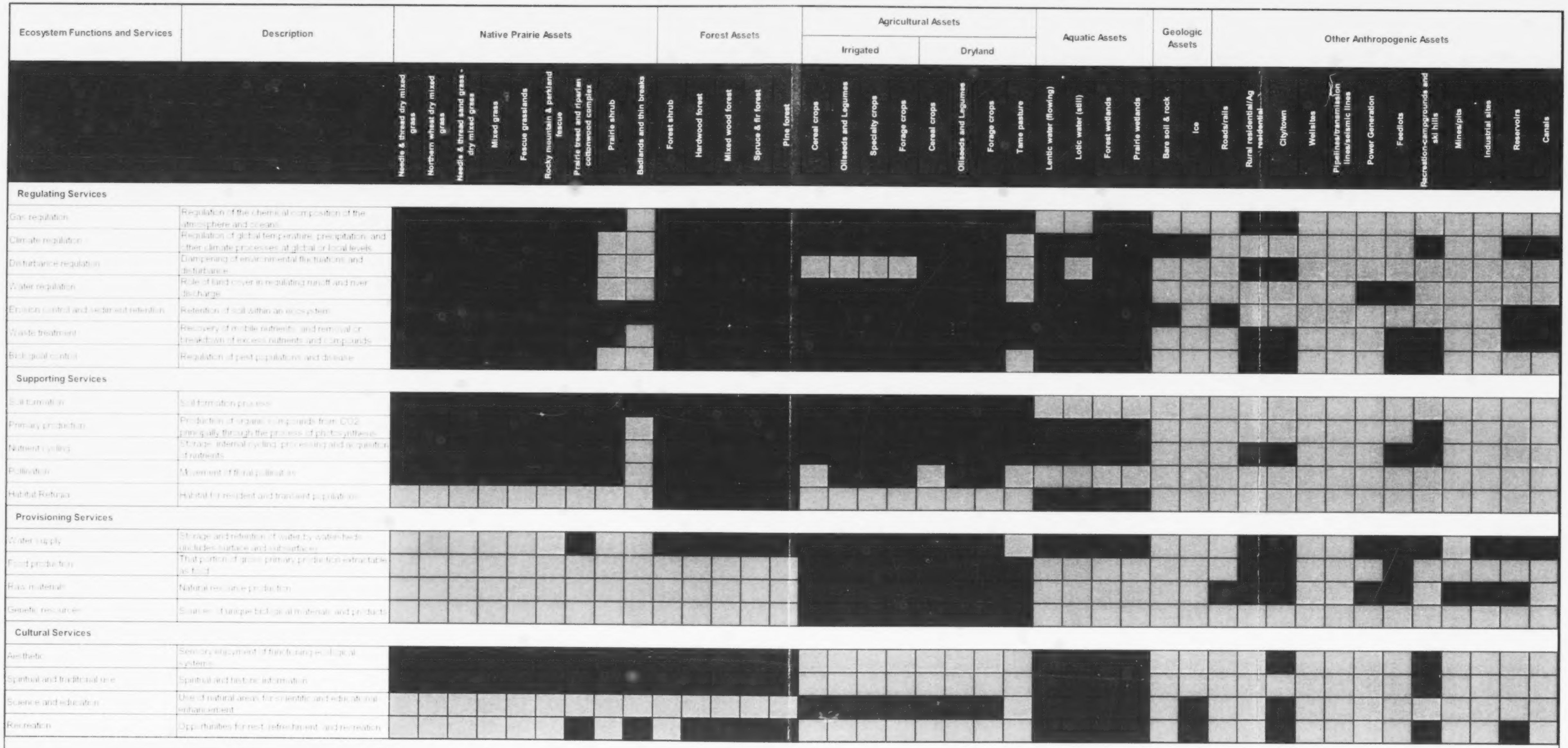
Positive	■
Somewhat positve	▒
Neutral	░
Somewhat Negative	□
Negative	□

Appendix 9-3: Importance of Ecosystem Services to the Maintenance of Assets

Ecosystem Functions and Services	Description	Native Prairie Assets									Forest Assets					Agricultural Assets								Aquatic Assets				Geologic Assets		Other Anthropogenic Assets											
																Irrigated				Dryland																					
		Needle & thread dry mixed grass	Northern wheat dry mixed grass	Needle & thread sand grass - dry mixed grass	Mixed grass	Fescue grasslands	Rocky mountain & parkland fescue	Prairie treed and riparian cottonwood complex	Prairie shrub	Badlands and thin breaks	Forest shrub	Hardwood forest	Mixed wood forest	Spruce & fir forest	Pine forest	Cereal crops	Oilseeds and Legumes	Specialty crops	Forage crops	Cereal crops	Oilseeds and Legumes	Forage crops	Tame pasture	Lentic water (flowing)	Lotic water (still)	Forest wetlands	Prairie wetlands	Bare soil & rock	Ice	Roads/rails	Rural residential/Ag residential	City/town	Wellsites	Pipelines/transmission lines/seismic lines	Power Generation	Feedlots	Recreation-campgrounds and ski hills	Mines/pits	Industrial sites	Reservoirs	Canals
Regulating Services																																									
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans																																								
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels																																								
Disturbance regulation	Dampening of environmental fluctuations and disturbance																																								
Water regulation	Role of land cover in regulating runoff and river discharge																																								
Erosion control and sediment retention	Retention of soil within an ecosystem																																								
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds																																								
Biological control	Regulation of pest populations and disease																																								
Supporting Services																																									
Soil formation	Soil formation process																																								
Primary production	Production of organic compounds from CO2, principally through the process of photosynthesis																																								
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients																																								
Pollination	Movement of floral pollinators																																								
Habitat/Refugia	Habitat for resident and transient populations																																								
Provisioning Services																																									
Water supply	Storage and retention of water by watersheds (includes surface and subsurface)																																								
Food production	That portion of gross primary production extractable as food																																								
Raw materials	Natural resource production																																								
Genetic resources	Sources of unique biological materials and products																																								
Cultural Services																																									
Aesthetic	Sensory enjoyment of functioning ecological systems																																								
Spiritual and traditional use	Spiritual and historic information																																								
Science and education	Use of natural areas for scientific and educational enhancement																																								
Recreation	Opportunities for rest, refreshment, and recreation																																								

Of Low Importance or Not Applicable (1)	
Of Moderate Importance (2)	
Of High Importance (3)	

Appendix 9-3: Importance of Ecosystem Services to the Maintenance of Assets


Native Prairie Assets
Needle & thread dry mixed grass
Northern wheat dry mixed grass
Needle & thread sand grass - dry mixed grass
Mixed grass
Fescue grasslands
Rocky mountain & parkland fescue
Prairie treed and riparian cottonwood complex
Prairie shrub
Badlands and thin breaks
Forest Assets
Forest shrub
Hardwood forest
Mixed wood forest
Spruce & fir forest
Pine forest
Agricultural Assets
Irrigated
Cereal crops
Oilseeds and Legumes
Specialty crops
Forage crops
Dryland
Cereal crops
Oilseeds and Legumes
Forage crops
Tame pasture
Aquatic Assets
Lentic water (flowing)
Lotic water (still)
Forest wetlands
Prairie wetlands
Geologic Assets
Bare soil & rock
Ice
Other Anthropogenic Assets
Roads/rails
Rural residential/Ag residential
City/town
Wellsites
Pipelines/transmission lines/seismic lines
Power Generation
Feedlots
Recreation-campgrounds and ski hills
Mines/pits
Industrial sites
Reservoirs
Canals

Ecosystem Functions and Services	Description
Regulating Services	
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels
Disturbance regulation	Dampening of environmental fluctuations and disturbance
Water regulation	Role of land cover in regulating runoff and river discharge
Erosion control and sediment retention	Retention of soil within an ecosystem
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds
Biological control	Regulation of pest populations and disease
Supporting Services	
Soil formation	Soil formation process
Primary production	Production of organic compounds from CO2 principally through the process of photosynthesis
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients
Pollination	Movement of floral pollinators
Habitat Refugia	Habitat for resident and transient populations
Provisioning Services	
Water supply	Storage and retention of water by watersheds (includes surface and subsurface)
Food production	That portion of gross primary production extractable as food
Raw materials	Natural resource production
Genetic resources	Sources of unique biological materials and products
Cultural Services	
Aesthetic	Sensory enjoyment of functioning ecological systems
Spiritual and traditional use	Spiritual and historic information
Science and education	Use of natural areas for scientific and educational enhancement
Recreation	Opportunities for rest, refreshment, and recreation

Of Low Importance or Not Applicable (1)	░
Of Moderate Importance (2)	▒
Of High Importance (3)	█

Appendix 9-4: Importance of Ecosystem Services to the Production of Goods

Ecosystem Functions and Services	Description	Primary Industry						Secondary Sector of Industry			Tertiary Sector of Industry							Cultural and Aesthetic Goods				
		Agriculture - Crop/Vegetable	Agriculture - Livestock	Oil & gas	Forestry	Mining	Subsistence	Agriculture processing	Oil & gas refining	Other manufacturing	Construction	Transportation & utilities	Trade (wholesale/retail)	Health & education	Tourist services	Government & non-profit	Other services	Biodiversity	Aesthetic	Cultural	Future options	Non-market recreational opportunities
Regulating Services																						
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans																					
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels																					
Disturbance regulation	Dampening of environmental fluctuations and disturbance																					
Water regulation	Role of land cover in regulating runoff and river discharge																					
Erosion control and sedime	Retention of soil within an ecosystem																					
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds																					
Biological control	Regulation of pest populations and disease																					
Supporting Services																						
Soil formation	Soil formation process																					
Primary production	Production of organic compounds from CO2, principally through the process of photosynthesis.																					
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients																					
Pollination	Movement of floral pollinators																					
Habitat/Refugia	Habitat for resident and transient populations																					
Provisioning Services																						
Water supply	Storage and retention of water by watersheds (includes surface and subsurface)																					
Food production	That portion of gross primary production extractable as food																					
Raw materials	Natural resource production																					
Genetic resources	Sources of unique biological materials and products																					
Cultural Services																						
Aesthetic	Sensory enjoyment of functioning ecological systems																					
Spiritual and traditional use	Spiritual and historic information																					
Science and education	Use of natural areas for scientific and educational enhancement																					
Recreation	Opportunities for rest, refreshment, and recreation																					

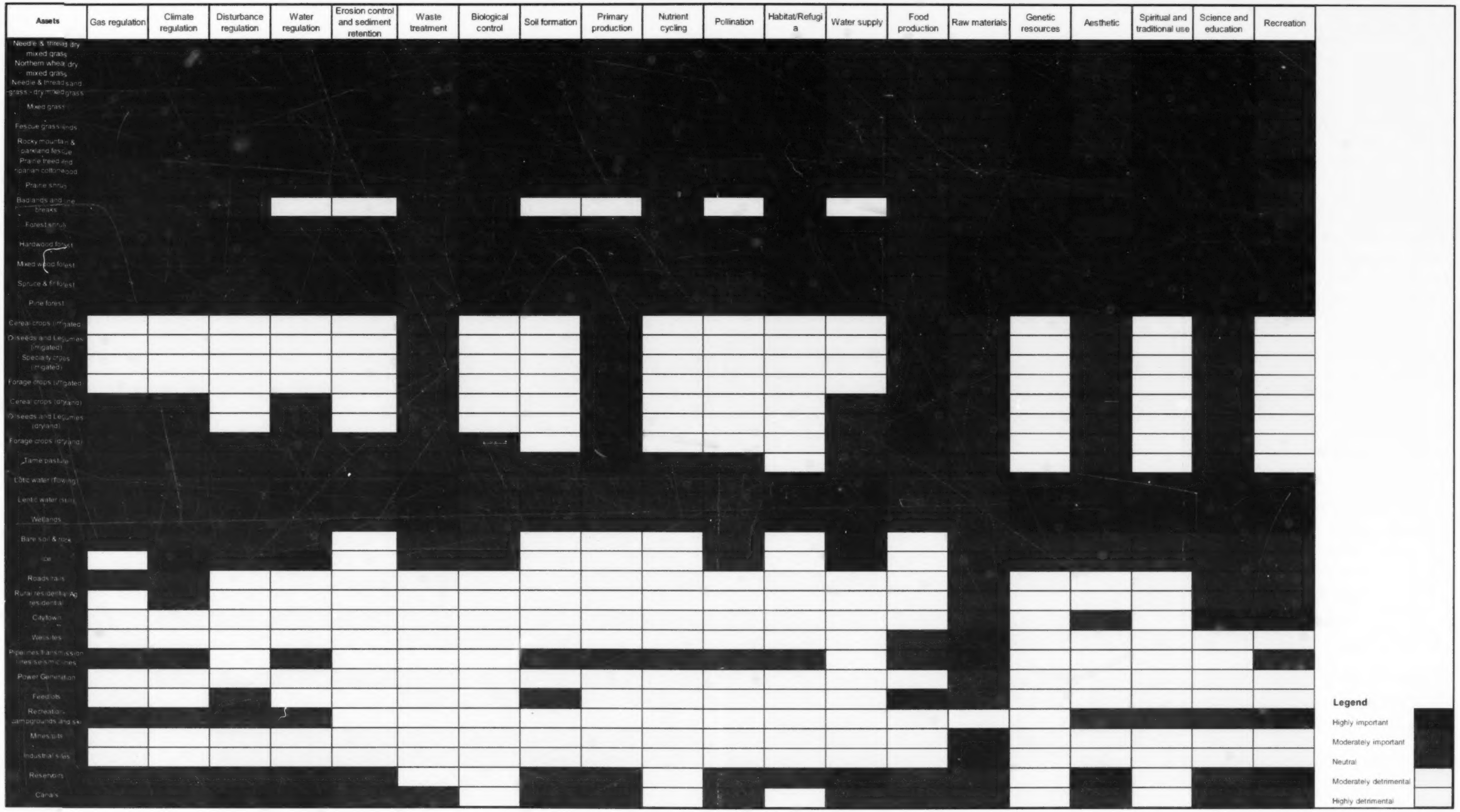
Of Low Importance or Not Applicable (1)	
Of Moderate Importance (2)	
Of High Importance (3)	

Appendix 9-4: Importance of Ecosystem Services to the Production of Goods

Ecosystem Functions and Services	Description	Primary Industry						Secondary Sector of Industry			Tertiary Sector of Industry							Cultural and Aesthetic Goods				
		Agriculture - Crop/Vegetable	Agriculture - Livestock	Oil & gas	Forestry	Mining	Subsistence	Agriculture processing	Oil & gas refining	Other manufacturing	Construction	Transportation & utilities	Trade (wholesale/retail)	Health & education	Tourist services	Government & non-profit	Other services	Biodiversity	Aesthetic	Cultural	Future options	Non-market recreational opportunities
Regulating Services																						
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	■	■	░	■	░	■	░	░	░	░	░	░	■	■	■	░	■	■	░	■	■
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels	■	■	░	■	░	■	░	░	░	░	░	░	░	■	■	░	■	■	░	■	■
Disturbance regulation	Dampening of environmental fluctuations and disturbance	■	░	░	■	░	■	░	░	░	░	░	░	░	■	■	░	■	■	░	■	■
Water regulation	Role of land cover in regulating runoff and river discharge	■	■	░	■	░	■	░	░	░	░	░	░	░	░	░	░	■	■	░	■	■
Erosion control and sedime	Retention of soil within an ecosystem	■	░	░	■	■	░	░	░	░	░	░	░	░	░	░	░	■	░	░	■	░
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds	■	■	░	░	░	░	░	░	░	░	░	░	■	░	░	░	░	░	░	■	░
Biological control	Regulation of pest populations and disease	■	■	░	■	░	■	░	░	░	░	░	░	■	■	■	░	■	░	░	■	■
Supporting Services																						
Soil formation	Soil formation process	■	░	░	■	░	░	░	░	░	░	░	░	░	░	░	░	■	░	░	■	░
Primary production	Production of organic compounds from CO2, principally through the process of photosynthesis	■	■	░	■	░	■	■	░	░	■	░	░	■	■	░	░	■	■	■	■	■
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	■	░	░	■	░	░	░	░	░	░	░	░	░	░	░	░	■	░	░	■	░
Pollination	Movement of floral pollinators	■	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	■	■	■	■	░
Habitat Refugia	Habitat for resident and transient populations	░	░	░	░	░	■	░	░	░	░	░	░	░	░	░	░	■	░	░	■	░
Provisioning Services																						
Water supply	Storage and retention of water by watersheds (includes surface and subsurface)	■	■	░	■	░	■	░	░	░	░	■	░	░	■	░	░	■	■	■	■	■
Food production	That portion of gross primary production extractable as food	■	■	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	■	░
Raw materials	Natural resource production	■	░	■	■	■	░	░	■	■	■	■	■	░	░	░	░	░	░	░	■	░
Genetic resources	Sources of unique biological materials and products	■	■	░	■	░	░	░	░	■	░	░	░	░	░	░	░	■	░	░	■	░
Cultural Services																						
Aesthetic	Sensory enjoyment of functioning ecological systems	░	░	░	░	░	░	░	░	░	░	░	░	░	■	░	░	░	■	■	■	■
Spiritual and traditional use	Spiritual and historic information	░	░	░	░	░	■	░	░	░	░	░	░	░	■	░	░	░	■	■	■	■
Science and education	Use of natural areas for scientific and educational enhancement	░	░	░	░	░	░	░	░	░	░	░	░	■	■	░	░	■	░	░	■	░
Recreation	Opportunities for rest, refreshment, and recreation	░	░	░	░	░	░	░	░	░	░	░	░	■	■	■	░	░	■	■	■	■

Of Low Importance or Not Applicable (1)	░
Of Moderate Importance (2)	▒
Of High Importance (3)	■

Appendix 9-5: Importance of Assets to the Provision of Services

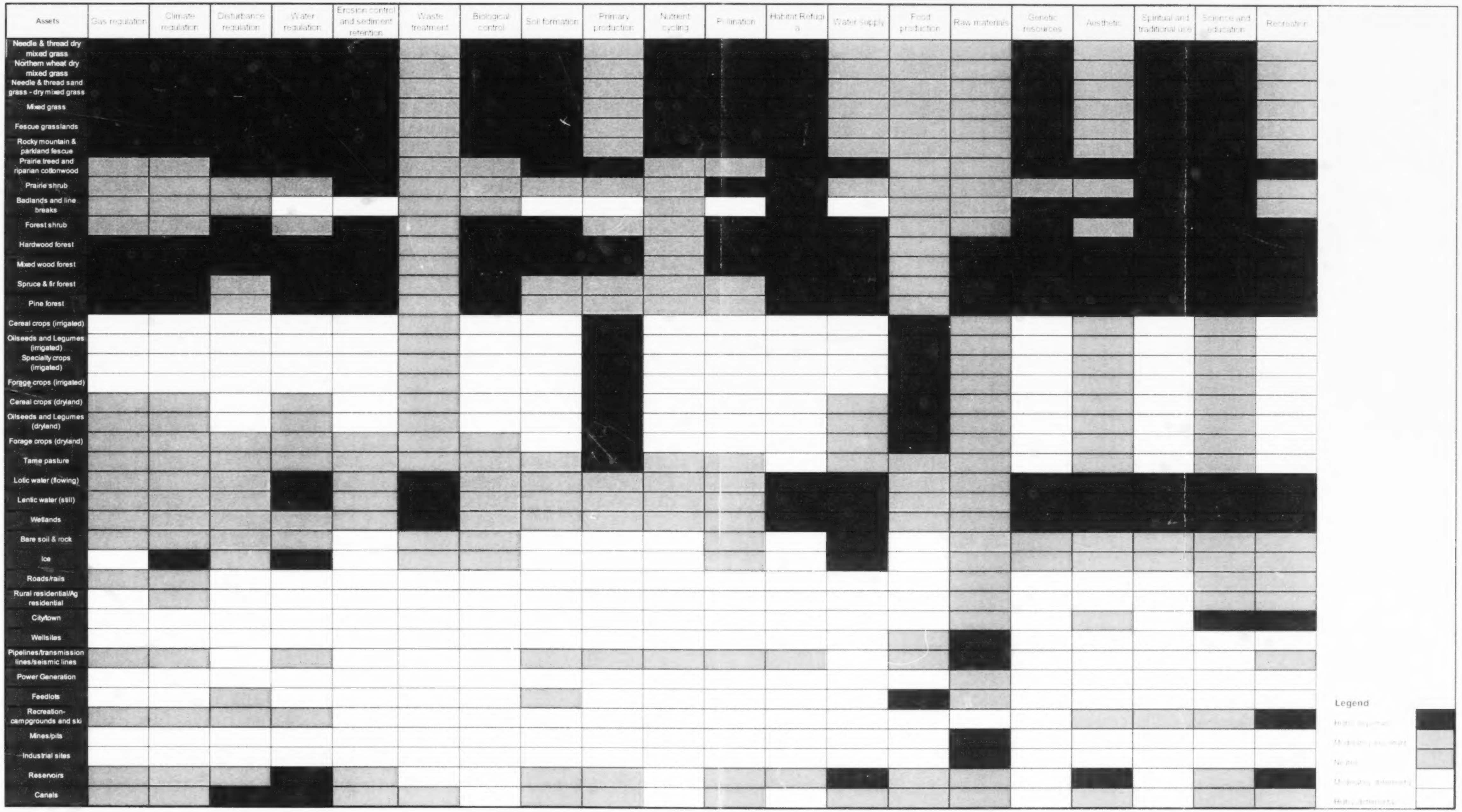


Assets	Gas regulation	Climate regulation	Disturbance regulation	Water regulation	Erosion control and sediment retention	Waste treatment	Biological control	Soil formation	Primary production	Nutrient cycling	Pollination	Habitat/Refugia	Water supply	Food production	Raw materials	Genetic resources	Aesthetic	Spiritual and traditional use	Science and education	Recreation
Needle & thread dry mixed grass	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Northern wheat dry mixed grass	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Needle & thread sand grass - dry mixed grass	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Mixed grass	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Fescue grasslands	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Rocky mountain & parkland fescue	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Prairie treed and riparian cottonwood	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Prairie shrub	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Badlands and [illegible] breaks	■	■	■	□	□	■	■	□	□	■	□	■	□	■	■	■	■	■	■	■
Forest shrub	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Hardwood forest	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Mixed wood forest	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Spruce & fir forest	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Pine forest	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Cereal crops (irrigated)	□	□	□	□	□	■	□	□	■	□	□	□	□	■	■	□	■	□	■	□
Oilseeds and Legumes (irrigated)	□	□	□	□	□	■	□	□	■	□	□	□	□	■	■	□	■	□	■	□
Specialty crops (irrigated)	□	□	□	□	□	■	□	□	■	□	□	□	□	■	■	□	■	□	■	□
Forage crops (irrigated)	□	□	□	□	□	■	□	□	■	□	□	□	□	■	■	□	■	□	■	□
Cereal crops (dryland)	■	■	□	■	□	■	□	□	■	□	□	□	■	■	■	□	■	□	■	□
Oilseeds and Legumes (dryland)	■	■	□	■	□	■	□	□	■	□	□	□	■	■	■	□	■	□	■	□
Forage crops (dryland)	■	■	■	■	■	■	■	□	■	□	□	□	■	■	■	□	■	□	■	□
Tame pasture	■	■	■	■	■	■	■	■	■	■	■	□	■	■	■	□	■	□	■	□
Lotic water (flowing)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Lentic water (still)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Wetlands	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Bare soil & rock	■	■	■	■	□	■	■	□	□	□	■	□	■	□	■	■	■	■	■	■
Ice	□	■	■	■	□	■	■	□	□	□	■	□	■	□	■	■	■	■	■	■
Roads/rails	■	■	□	□	□	□	□	□	□	□	□	□	□	□	■	□	□	□	■	■
Rural residential/Ag residential	□	■	□	□	□	□	□	□	□	□	□	□	□	□	■	□	□	□	■	■
City/town	□	□	□	□	□	□	□	□	□	□	□	□	□	□	■	□	■	□	■	■
Wellsites	□	□	□	□	□	□	□	□	□	□	□	□	□	■	■	□	□	□	□	□
Pipelines/transmission lines/seismic lines	■	■	□	■	□	□	□	■	■	■	■	■	□	■	■	□	□	□	□	■
Power Generation	□	□	□	□	□	□	□	□	□	□	□	□	□	□	■	□	□	□	□	□
Feedlots	□	□	■	□	□	□	□	■	□	□	□	□	□	■	■	□	□	□	□	□
Recreation-campgrounds and ski	■	■	■	■	□	□	□	□	□	□	□	□	□	□	□	□	■	■	■	■
Mines/pits	□	□	□	□	□	□	□	□	□	□	□	□	□	□	■	□	□	□	□	□
Industrial sites	□	□	□	□	□	□	□	□	□	□	□	□	□	□	■	□	□	□	□	□
Reservoirs	■	■	■	■	■	□	□	■	■	□	■	■	■	■	■	□	■	□	■	■
Canals	■	■	■	■	■	■	□	■	■	□	■	□	■	■	■	□	■	□	■	■

Legend

Highly important	■
Moderately important	■
Neutral	■
Moderately detrimental	□
Highly detrimental	□

Appendix 9-5: Importance of Assets to the Provision of Services

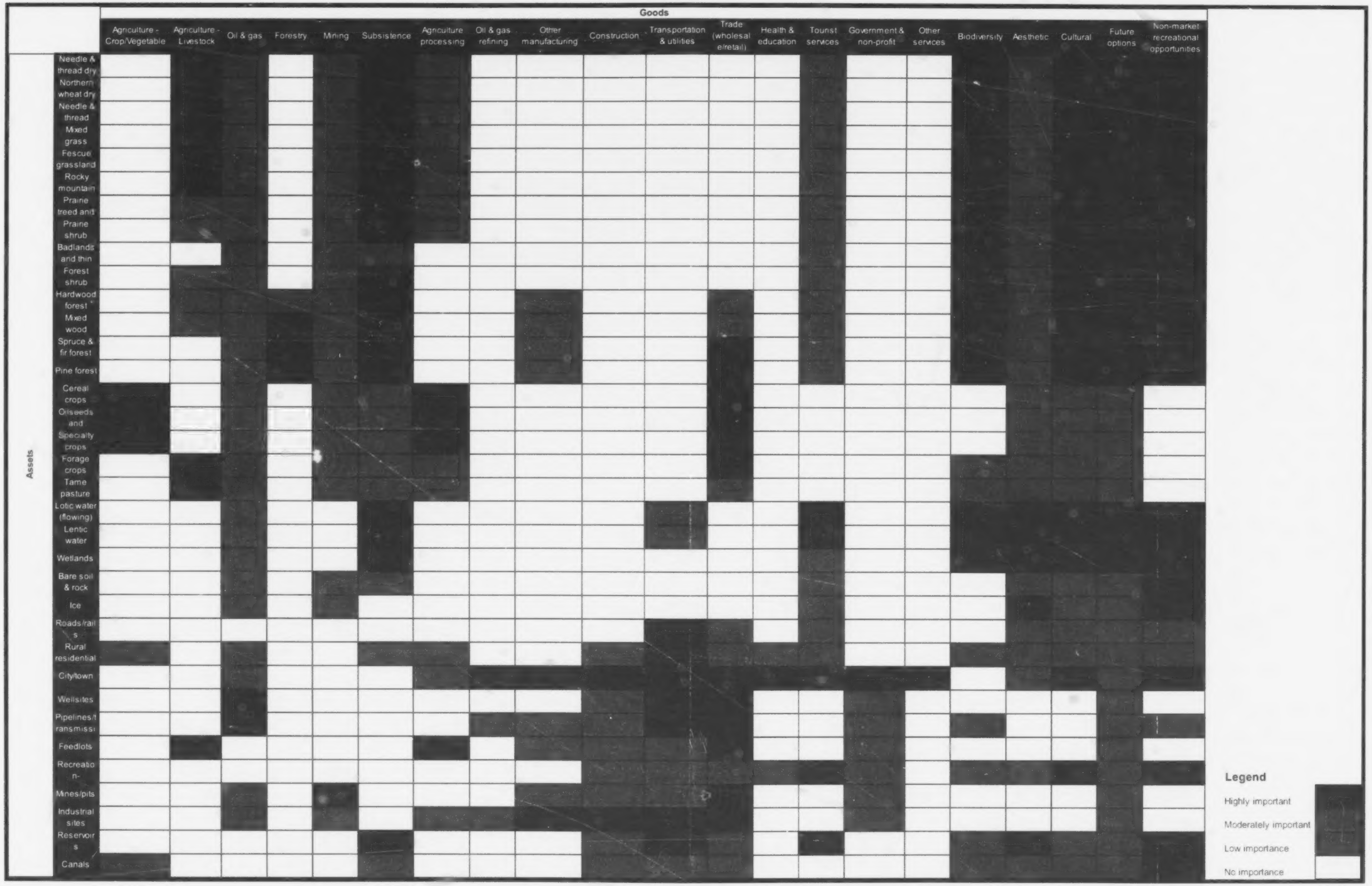


Assets	Gas regulation	Climate regulation	Disturbance regulation	Water regulation	Erosion control and sediment retention	Waste treatment	Biological control	Soil formation	Primary production	Nutrient cycling	Pollination	Habitat Refugia	Water supply	Food production	Raw materials	Genetic resources	Aesthetic	Spiritual and traditional use	Science and education	Recreation
Needle & thread dry mixed grass	■	■	■	■	■	▒	■	■	▒	■	■	■	▒	▒	▒	■	▒	■	■	▒
Northern wheat dry mixed grass	■	■	■	■	■	▒	■	■	▒	■	■	■	▒	▒	▒	■	▒	■	■	▒
Needle & thread sand grass - dry mixed grass	■	■	■	■	■	▒	■	■	▒	■	■	■	▒	▒	▒	■	▒	■	■	▒
Mixed grass	■	■	■	■	■	▒	■	■	▒	■	■	■	▒	▒	▒	■	▒	■	■	▒
Fescue grasslands	■	■	■	■	■	▒	■	■	▒	■	■	■	▒	▒	▒	■	▒	■	■	▒
Rocky mountain & parkland fescue	■	■	■	■	■	▒	■	■	▒	■	■	■	▒	▒	▒	■	▒	■	■	▒
Prairie treed and riparian cottonwood	▒	▒	■	■	■	▒	▒	■	■	▒	▒	■	■	▒	▒	■	■	■	■	■
Prairie shrub	▒	▒	▒	▒	■	▒	▒	▒	▒	▒	■	■	▒	▒	▒	▒	▒	■	■	▒
Badlands and line breaks	▒	▒	▒	□	□	▒	▒	□	□	▒	□	■	□	▒	▒	■	■	■	■	▒
Forest shrub	▒	▒	■	▒	■	▒	■	■	▒	▒	■	■	■	▒	▒	■	▒	■	■	■
Hardwood forest	■	■	■	■	■	▒	■	■	■	▒	■	■	■	▒	■	■	■	■	■	■
Mixed wood forest	■	■	■	■	■	▒	■	■	■	▒	■	■	■	▒	■	■	■	■	■	■
Spruce & fir forest	■	■	▒	■	■	▒	■	▒	▒	▒	▒	■	■	▒	■	■	■	■	■	■
Pine forest	■	■	▒	■	■	▒	■	▒	▒	▒	▒	■	■	▒	■	■	■	■	■	■
Cereal crops (irrigated)	□	□	□	□	□	▒	□	□	■	□	□	□	□	■	▒	□	▒	□	▒	□
Oilseeds and Legumes (irrigated)	□	□	□	□	□	▒	□	□	■	□	□	□	□	■	▒	□	▒	□	▒	□
Specialty crops (irrigated)	□	□	□	□	□	▒	□	□	■	□	□	□	□	■	▒	□	▒	□	▒	□
Forage crops (irrigated)	□	□	□	□	□	▒	□	□	■	□	□	□	□	■	▒	□	▒	□	▒	□
Cereal crops (dryland)	▒	▒	□	▒	□	▒	□	□	■	□	□	□	▒	■	▒	□	▒	□	▒	□
Oilseeds and Legumes (dryland)	▒	▒	□	▒	□	▒	□	□	■	□	□	□	▒	■	▒	□	▒	□	▒	□
Forage crops (dryland)	▒	▒	▒	▒	▒	▒	▒	□	■	□	□	□	▒	■	▒	□	▒	□	▒	□
Tame pasture	▒	▒	▒	▒	▒	▒	▒	▒	■	▒	▒	□	▒	▒	▒	□	▒	□	▒	□
Lotic water (flowing)	▒	▒	▒	■	▒	■	▒	▒	▒	▒	▒	■	■	▒	▒	■	■	■	■	■
Lentic water (still)	▒	▒	▒	■	▒	■	▒	▒	▒	▒	▒	■	■	▒	▒	■	■	■	■	■
Wetlands	▒	▒	▒	▒	▒	■	▒	▒	▒	▒	▒	■	■	▒	▒	■	■	■	■	■
Bare soil & rock	▒	▒	▒	▒	□	▒	▒	□	□	□	▒	□	■	□	▒	▒	▒	▒	▒	▒
Ice	□	■	▒	■	□	▒	▒	□	□	□	▒	□	■	□	▒	▒	▒	▒	▒	▒
Roads/rails	▒	▒	□	□	□	□	□	□	□	□	□	□	□	□	▒	□	□	□	▒	▒
Rural residential/Ag residential	□	▒	□	□	□	□	□	□	□	□	□	□	□	□	▒	□	□	□	▒	▒
City/town	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▒	□	▒	□	■	■
Wellsites	□	□	□	□	□	□	□	□	□	□	□	□	□	▒	■	□	□	□	□	□
Pipelines/transmission lines/seismic lines	▒	▒	□	▒	□	□	□	▒	▒	▒	▒	▒	□	▒	■	□	□	□	□	▒
Power Generation	□	□	□	□	□	□	□	□	□	□	□	□	□	□	▒	□	□	□	□	□
Feedlots	□	□	▒	□	□	□	□	▒	□	□	□	□	□	■	▒	□	□	□	□	□
Recreation-campgrounds and ski	▒	▒	▒	▒	□	□	□	□	□	□	□	□	□	□	□	□	▒	▒	▒	■
Mines/pits	□	□	□	□	□	□	□	□	□	□	□	□	□	□	■	□	□	□	□	□
Industrial sites	□	□	□	□	□	□	□	□	□	□	□	□	□	□	■	□	□	□	□	□
Reservoirs	▒	▒	▒	■	▒	□	□	▒	▒	□	▒	▒	■	▒	▒	□	■	□	▒	■
Canals	▒	▒	■	■	▒	▒	□	▒	▒	□	▒	□	▒	▒	▒	□	▒	□	▒	▒

Legend

Highly important	■
Moderately important	▒
Neutral	▒
Moderately detrimental	□
Highly detrimental	□

Appendix 9-6: Importance of Assets to the Production of Goods



Assets	Agriculture - Crop/Vegetable	Agriculture - Livestock	Oil & gas	Forestry	Mining	Subsistence	Agriculture processing	Oil & gas refining	Other manufacturing	Construction	Transportation & utilities	Trade (wholesale/retail)	Health & education	Tourist services	Government & non-profit	Other services	Biodiversity	Aesthetic	Cultural	Future options	Non-market recreational opportunities
Needle & thread dry		■	■		■	■	■							■			■	■	■	■	■
Northern wheat dry		■	■		■	■	■							■			■	■	■	■	■
Needle & thread		■	■		■	■	■							■			■	■	■	■	■
Mixed grass		■	■		■	■	■							■			■	■	■	■	■
Fescue grassland		■	■		■	■	■							■			■	■	■	■	■
Rocky mountain		■	■		■	■	■							■			■	■	■	■	■
Praire treed and		■	■		■	■	■							■			■	■	■	■	■
Praire shrub		■	■		■	■	■							■			■	■	■	■	■
Badlands and thin			■		■	■								■			■	■	■	■	■
Forest shrub		■	■		■	■								■			■	■	■	■	■
Hardwood forest		■	■	■	■	■			■			■		■			■	■	■	■	■
Mixed wood		■	■	■	■	■			■			■		■			■	■	■	■	■
Spruce & fir forest			■	■	■	■			■			■		■			■	■	■	■	■
Pine forest			■	■	■	■			■			■		■			■	■	■	■	■
Cereal crops	■		■		■	■	■					■						■	■	■	
Oilseeds and	■		■		■	■	■					■						■	■	■	
Specialty crops	■		■		■	■	■					■						■	■	■	
Forage crops		■	■		■	■	■					■					■	■	■	■	
Tame pasture		■	■		■	■	■					■					■	■	■	■	
Lotic water (flowing)			■			■					■			■			■	■	■	■	■
Lentic water			■			■					■			■			■	■	■	■	■
Wetlands			■			■								■			■	■	■	■	■
Bare soil & rock			■		■	■								■				■	■	■	■
Ice			■		■									■				■	■	■	■
Roads/rails											■	■		■				■	■	■	■
Rural residential	■		■			■	■			■	■	■	■	■			■	■	■	■	■
City/town			■				■	■	■	■	■	■	■	■	■	■		■	■	■	■
Wellsites			■							■	■	■			■					■	
Pipelines/transmissi			■					■	■	■	■	■			■		■			■	■
Feedlots		■					■		■	■	■	■			■					■	
Recreation-										■	■	■	■	■	■		■	■	■	■	■
Mines/pits			■		■				■	■	■	■			■					■	
Industrial sites			■		■		■	■	■	■	■	■			■					■	
Reservoirs						■				■	■	■		■			■	■	■	■	■
Canals	■					■				■	■	■					■	■	■	■	■

Legend

Highly important ■

Moderately important ■

Low importance ■

No importance □

Appendix 9-6: Importance of Assets to the Production of Goods

	Goods																				
Assets	Agriculture - Crop/Vegetable	Agriculture - Livestock	Oil & gas	Forestry	Mining	Subsistence	Agriculture processing	Oil & gas refining	Other manufacturing	Construction	Transportation & utilities	Trade (wholesale/retail)	Health & education	Tourist services	Government & non-profit	Other services	Biodiversity	Aesthetic	Cultural	Future options	Non-market recreational opportunities
Needle & thread dry		■	▒		▒	■	▒							▒			■	▒	■	■	■
Northern wheat dry		■	▒		▒	■	▒							▒			■	▒	■	■	■
Needle & thread		■	▒		▒	■	▒							▒			■	▒	■	■	■
Mixed grass		■	▒		▒	■	▒							▒			■	▒	■	■	■
Fescue grassland		■	▒		▒	■	▒							▒			■	▒	■	■	■
Rocky mountain		■	▒		▒	■	▒							▒			■	▒	■	■	■
Prairie treed and		▒	▒		▒	■	▒							▒			■	▒	■	■	■
Prairie shrub		▒	▒		▒	■	▒							▒			■	▒	■	■	■
Badlands and thin			▒		▒	▒								▒			■	▒	■	■	■
Forest shrub		▒	▒		▒	■								▒			■	▒	■	■	■
Hardwood forest		▒	▒	▒	▒	■			▒			▒		▒			■	▒	■	■	■
Mixed wood		▒	▒	■	▒	■			▒			▒		▒			■	▒	■	■	■
Spruce & fir forest			▒	■	▒	■			▒			■		▒			■	▒	■	■	■
Pine forest			▒	■	▒	■			▒			■		▒			■	▒	■	■	■
Cereal crops	■		▒		▒	▒	■					■						▒	▒	▒	
Oilseeds and	■		▒		▒	▒	■					■						▒	▒	▒	
Specialty crops	■		▒		▒	▒	■					■						▒	▒	▒	
Forage crops		■	▒		▒	▒	▒					■					▒	▒	▒	▒	
Tame pasture		■	▒		▒	▒	▒					▒					▒	▒	▒	▒	
Lotic water (flowing)			▒			■					▒			■			■	■	■	■	■
Lentic water			▒			■					▒			■			■	■	■	■	■
Wetlands			▒			■								▒			■	■	■	■	■
Bare soil & rock			▒		▒	▒								▒				▒	▒	▒	■
Ice			▒		▒									▒				■	▒	▒	■
Roads/rails											■	▒		▒				▒	▒	▒	▒
Rural residential	▒		▒			▒	▒			▒	■	▒	▒	▒			▒	▒	▒	▒	▒
City/town			▒				▒	■	■	■	■	■	■	■	■	■		▒	■	▒	■
Wellsites			■							▒	■	■			▒					▒	
Pipelines/transmissi			■					▒	▒	▒	■	■			▒		▒			▒	▒
Feedlots		■					■		▒	▒	▒	■			▒					▒	
Recreation-										▒	▒	▒	▒	■	▒		▒	▒	■	▒	■
Mines/pits			▒		■				▒	▒	▒	■			▒					▒	
Industrial sites			▒		▒		▒	▒	■	■	■	■			▒					▒	
Reservoirs						■				▒	■	▒		■			▒	■	▒	▒	■
Canals	▒					▒				▒	▒	▒					▒	▒	▒	▒	■

Legend

Highly important	■
Moderately important	▒
Low importance	▒
No importance	

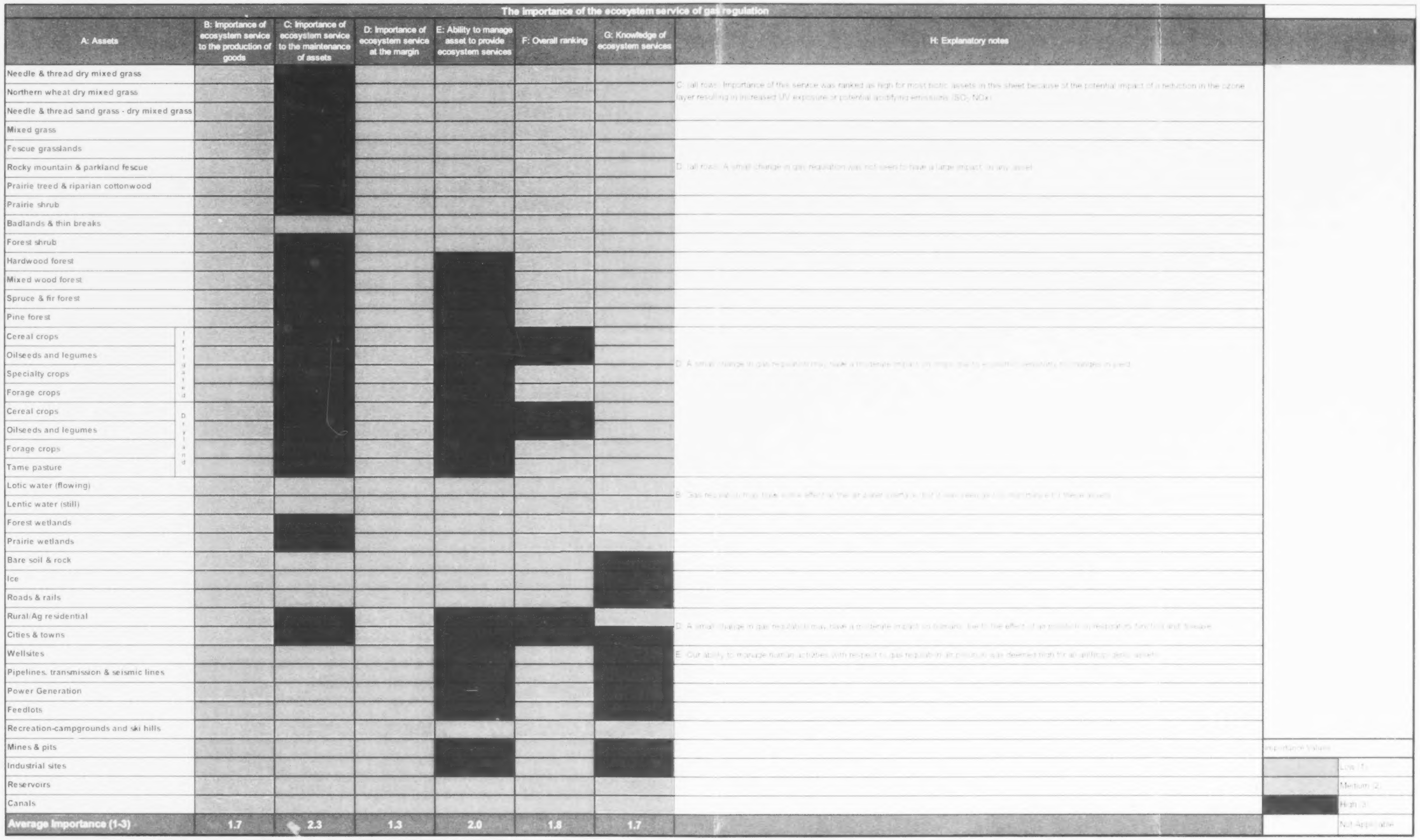
Appendix 9-7: Relative Importance of Ecosystem Services – Gas Regulation

The importance of the ecosystem service of gas regulation

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								C: (all rows) Importance of this service was ranked as high for most biotic assets in this sheet because of the potential impact of a reduction in the ozone layer resulting in increased UV exposure or potential acidifying emissions (SO_2/NOx).
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								
Mixed grass								
Fescue grasslands								D: (all rows) A small change in gas regulation was not seen to have a large impact on any asset.
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							D: A small change in gas regulation may have a moderate impact on crops due to economic sensitivity to changes in yield
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								B: Gas regulation may have some effect at the air/water interface, but it was seen as low importance for these assets
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								D: A small change in gas regulation may have a moderate impact on humans due to the effect of air pollution on respiratory function and disease.
Cities & towns								
Wellsites								E: Our ability to manage human activities with respect to gas regulation/air pollution was deemed high for all anthropogenic assets.
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								
Mines & pits								
Industrial sites								
Reservoirs								
Canals								
Average Importance (1-3)		1.7	2.3	1.3	2.0	1.8	1.7	

Importance Values	
	Low (1)
	Medium (2)
	High (3)
	Not Applicable

Appendix 9-7: Relative Importance of Ecosystem Services – Gas Regulation



The importance of the ecosystem service of gas regulation

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass		▒	█	▒	▒	▒	▒	C: (all rows): Importance of this service was ranked as high for most biotic assets in this sheet because of the potential impact of a reduction in the ozone layer resulting in increased UV exposure or potential acidifying emissions (SO_2, NOx).
Northern wheat dry mixed grass		▒	█	▒	▒	▒	▒	
Needle & thread sand grass - dry mixed grass		▒	█	▒	▒	▒	▒	
Mixed grass		▒	█	▒	▒	▒	▒	
Fescue grasslands		▒	█	▒	▒	▒	▒	D: (all rows): A small change in gas regulation was not seen to have a large impact on any asset.
Rocky mountain & parkland fescue		▒	█	▒	▒	▒	▒	
Prairie treed & riparian cottonwood		▒	█	▒	▒	▒	▒	
Prairie shrub		▒	█	▒	▒	▒	▒	
Badlands & thin breaks		▒	▒	▒	▒	▒	▒	
Forest shrub		▒	█	▒	▒	▒	▒	
Hardwood forest		▒	█	▒	█	▒	▒	
Mixed wood forest		▒	█	▒	█	▒	▒	
Spruce & fir forest		▒	█	▒	█	▒	▒	
Pine forest		▒	█	▒	█	▒	▒	
Cereal crops	Irrigated	▒	█	▒	█	█	▒	D: A small change in gas regulation may have a moderate impact on crops due to economic sensitivity to changes in yield.
Oilseeds and legumes		▒	█	▒	█	█	▒	
Specialty crops		▒	█	▒	█	▒	▒	
Forage crops		▒	█	▒	█	▒	▒	
Cereal crops	Dryland	▒	█	▒	█	█	▒	
Oilseeds and legumes		▒	█	▒	█	█	▒	
Forage crops		▒	█	▒	█	▒	▒	
Tame pasture		▒	█	▒	█	▒	▒	
Lotic water (flowing)		▒	▒	▒	▒	▒	▒	B: Gas regulation may have some effect at the air water interface but it was seen as not important to these assets.
Lentic water (still)		▒	▒	▒	▒	▒	▒	
Forest wetlands		▒	█	▒	▒	▒	▒	
Prairie wetlands		▒	█	▒	▒	▒	▒	
Bare soil & rock		▒	▒	▒	▒	▒	█	
Ice		▒	▒	▒	▒	▒	█	
Roads & rails		▒	▒	▒	▒	▒	█	
Rural/Ag residential		▒	█	▒	█	█	▒	D: A small change in gas regulation may have a moderate impact on humans due to the effect of air pollution on respiratory function and disease.
Cities & towns		▒	█	▒	█	█	█	
Wellsites		▒	▒	▒	█	▒	█	E: Our ability to manage human activities with respect to gas regulation (air pollution) was deemed high for all anthropogenic assets.
Pipelines, transmission & seismic lines		▒	▒	▒	█	▒	█	
Power Generation		▒	▒	▒	█	▒	█	
Feedlots		▒	▒	▒	█	▒	█	
Recreation-campgrounds and ski hills		▒	▒	▒	▒	▒	▒	
Mines & pits		▒	▒	▒	█	▒	█	
Industrial sites		▒	▒	▒	█	▒	█	
Reservoirs		▒	▒	▒	▒	▒	▒	
Canals		▒	▒	▒	▒	▒	▒	
Average Importance (1-3)		1.7	2.3	1.3	2.0	1.8	1.7	

Importance Values	
▒	Low (1)
▒	Medium (2)
█	High (3)
	Not Applicable

Appendix 9-8: Relative Importance of Ecosystem Services – Climate Regulation

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
		The importance of the ecosystem service of climate regulation						
Needle & thread dry mixed grass								C: (all rows) Importance of this service was ranked as high for most biotic assets in this sheet because of the potential impact of altered temperature and precipitation regimes.
Northern wheat dry mixed grass								D: (all rows) A relatively small change in global temperature could have a large impact on the biotic assets on this sheet
Needle & thread sand grass - dry mixed grass								
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								C: D: Values lower due to the presence of less biotic material and greater resiliency than other assets
Forest shrub								
Hardwood forest								E: (all rows) The ability to manage most assets was ranked low-med except for forests which are reasonably good carbon sinks.
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								C: Impact of potentially altered precipitation on hydrologic systems
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								C: Bare soil may be disturbed by higher precipitation
Ice								C: Ice melting with higher temperatures.
Roads & rails								
Rural/Ag residential								
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								
Mines & pits								
Industrial sites								
Reservoirs								C: Impact of potentially altered precipitation on hydrologic systems
Canals								
Average Importance (1-3)		1.9	2.5	2.2	1.4	2.0	2.1	

Importance Values	
	Low (1)
	Medium (2)
	High (3)
	Not Applicable

Appendix 9-9: Relative Importance of Ecosystem Services – Disturbance Regulation

		The importance of the ecosystem service of disturbance regulation						
A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								C: (all rows) Importance of this service was ranked as high for most biotic and some anthropogenic assets in this sheet because of the potential impact of extreme weather events.
Northern wheat dry mixed grass								E: (all rows) A relatively small change in the frequency of occurrence of extreme weather (hail storms, tornados) could have a large impact on the biotic and anthropogenic assets on this sheet
Needle & thread sand grass - dry mixed grass								
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								E: Higher because of the interdependence between riparian cottonwoods and the flood regime.
Prairie shrub								
Badlands & thin breaks								C: This asset type was seen as more resilient than others.
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								C: Extreme weather was deemed to impact rivers and streams more than lakes.
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								
Cities & towns								C: Sensitivity of the built environment to extreme weather events (hail, tornados, etc) and resulting financial impact.
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								D: Flooding in campgrounds is more likely for those on or near the floodplain.
Mines & pits								
Industrial sites								
Reservoirs								E: Reservoirs can be used to help manage floods.
Canals								
Average Importance (1-3)		1.8	2.5	2.5	1.5	2.0	2.1	

Importance Values	
	Low (1)
	Medium (2)
	High (3)
	Not Applicable

Appendix 9-10: Relative Importance of Ecosystem Services – Water Regulation

Table 10c. The importance of the ecosystem service of water regulation

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								C: (all rows) Importance of this service was ranked as high for most biotic assets in this sheet because of their reliance on a stable and reliable water source.
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								D: Higher because of the interdepencence between riparian cottonwoods and the flood regime
Prairie shrub								
Badlands & thin breaks								C: Deemed less sensitive to changes in water supply (less reliant on overland water supply)
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								
Mines & pits								
Industrial sites								
Reservoirs								E: Reservoirs can be used to manage water regulation
Canals								
Average Importance (1-3)		1.85	2.5	1.7	1.8	2.0	2.9	

Importance Values	
▨	Low (1)
▨	Medium (2)
■	High (3)
☐	Not Applicable

Appendix 9-11: Relative Importance of Ecosystem Services – Erosion Control and Sediment Retention

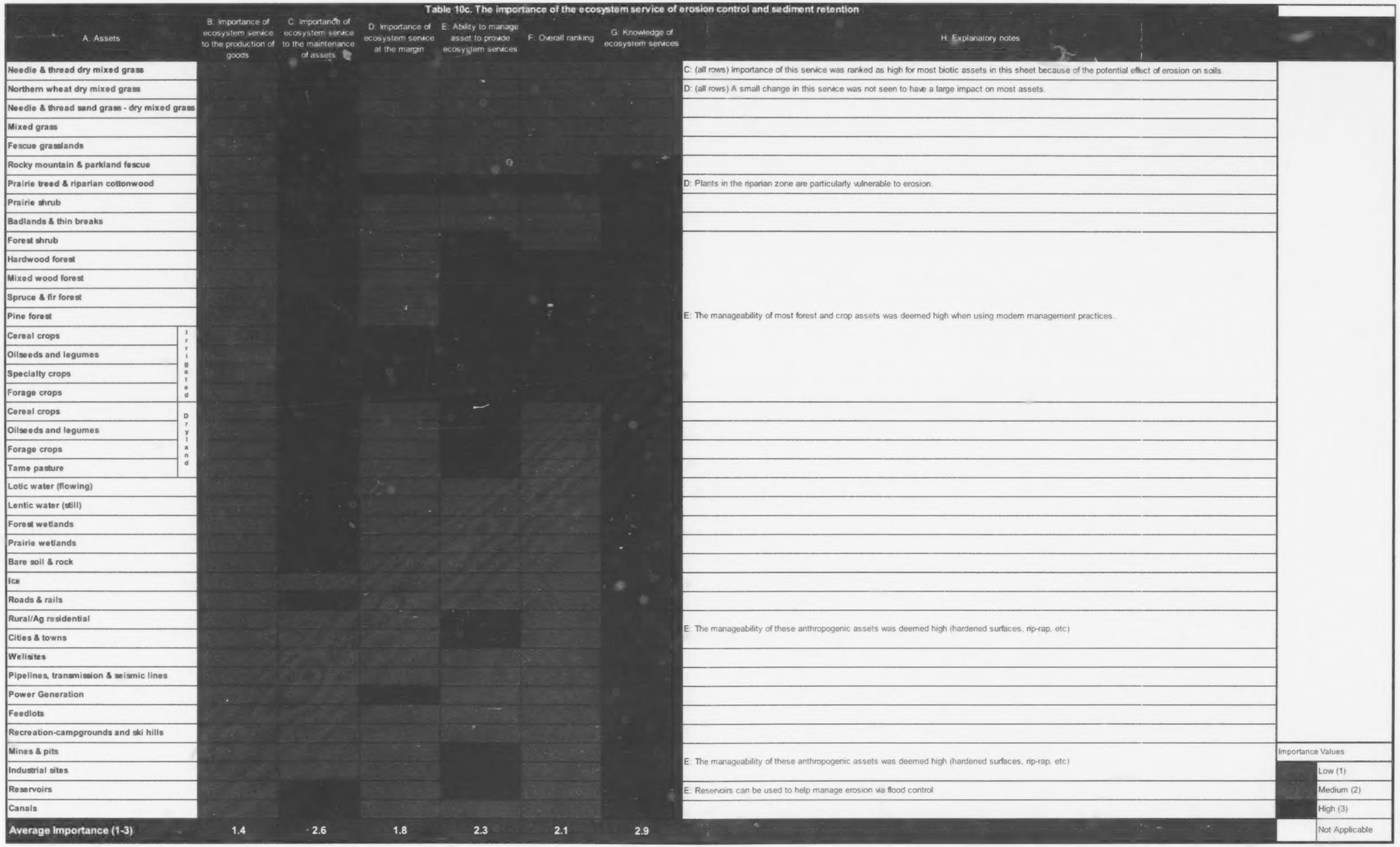


Table 10c. The importance of the ecosystem service of erosion control and sediment retention

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								C: (all rows) Importance of this service was ranked as high for most biotic assets in this sheet because of the potential effect of erosion on soils.
Northern wheat dry mixed grass								D: (all rows) A small change in this service was not seen to have a large impact on most assets.
Needle & thread sand grass - dry mixed grass								
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								D: Plants in the riparian zone are particularly vulnerable to erosion.
Prairie shrub								
Badlands & thin breaks								
Forest shrub								E: The manageability of most forest and crop assets was deemed high when using modern management practices.
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								E: The manageability of these anthropogenic assets was deemed high (hardened surfaces, rip-rap, etc)
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								
Mines & pits								E: The manageability of these anthropogenic assets was deemed high (hardened surfaces, rip-rap, etc)
Industrial sites								
Reservoirs								E: Reservoirs can be used to help manage erosion via flood control
Canals								
Average Importance (1-3)		1.4	2.6	1.8	2.3	2.1	2.9	

Importance Values	
▨	Low (1)
▨	Medium (2)
■	High (3)
☐	Not Applicable

Appendix 9-12: Relative Importance of Ecosystem Services – Waste Treatment

Table 10c. The importance of the ecosystem service of waste treatment

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								B: (all rows) The importance of this service to the production of goods may appear underrated due to the relatively low number goods produced by this service (despite the relatively high value of the goods). There is an indirect relationship between waste management and the production of goods (via maintenance of assets).
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								C: (all rows) Importance of this service was ranked as high for most biotic and anthropogenic assets in this sheet because of the potential effect of pollutants on living things (including humans), and the replacement cost of waste treatment.
Mixed grass								
Fescue grasslands								E: (all rows) Our ability to mange waste treatment function from engineered wetlands and most anthropogenic activities was deemed high
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								B: The importance of waste treatment is extremely important (see comment at top)
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								
Mines & pits								
Industrial sites								
Reservoirs								
Canals								
Average Importance (1-3)		1.1	2.6	2.0	1.9	2.0	2.3	

Importance Values	
▨	Low (1)
▨	Medium (2)
▨	High (3)
☐	Not Applicable

Appendix 9-13: Relative Importance of Ecosystem Services – Biological Control

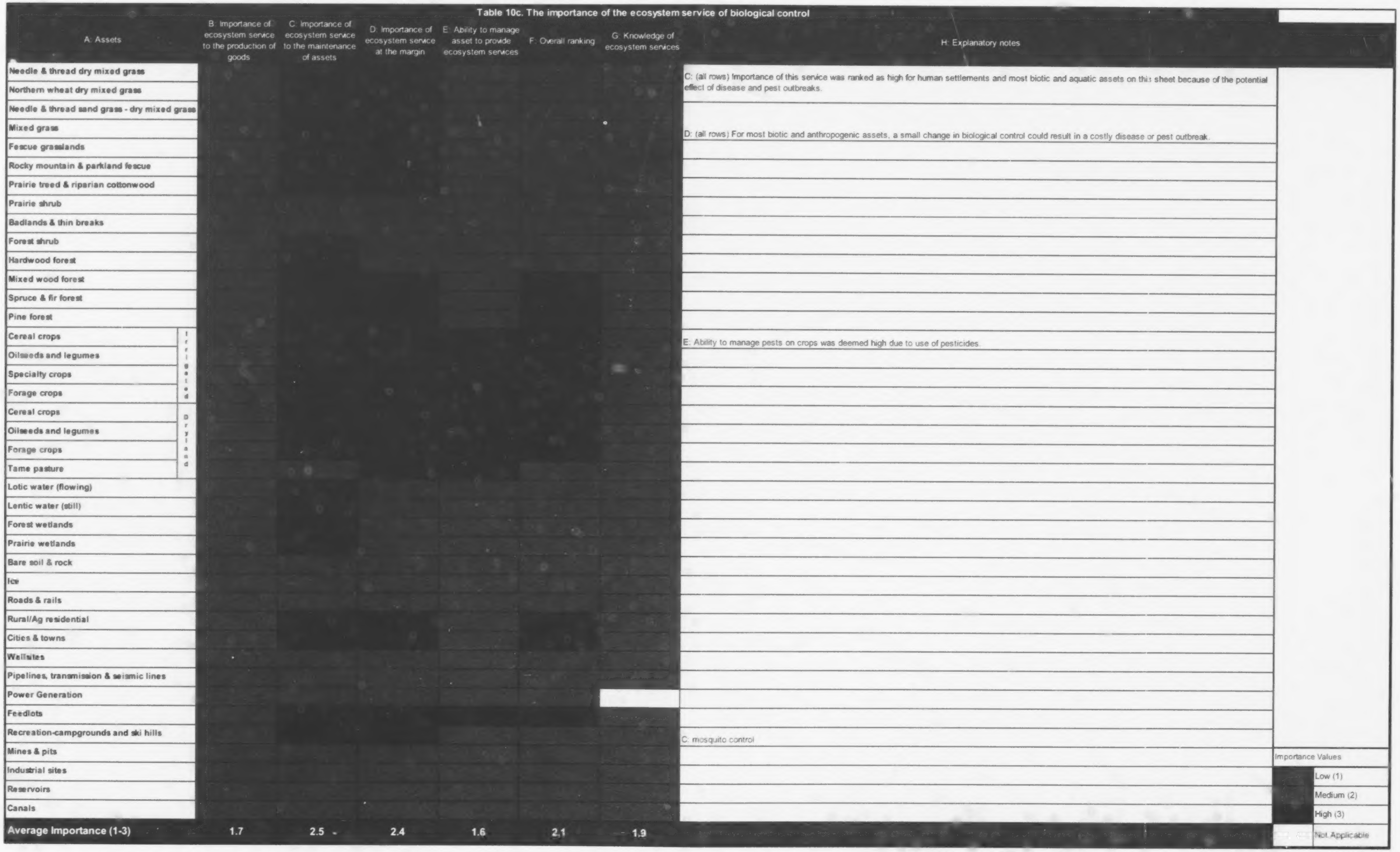


Table 10c. The importance of the ecosystem service of biological control

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								C: (all rows) Importance of this service was ranked as high for human settlements and most biotic and aquatic assets on this sheet because of the potential effect of disease and pest outbreaks.
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								
Mixed grass								D: (all rows) For most biotic and anthropogenic assets, a small change in biological control could result in a costly disease or pest outbreak.
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							E: Ability to manage pests on crops was deemed high due to use of pesticides.
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								C: mosquito control
Mines & pits								
Industrial sites								
Reservoirs								
Canals								
Average Importance (1-3)		1.7	2.5	2.4	1.6	2.1	1.9	

Importance Values	
■	Low (1)
■	Medium (2)
■	High (3)
□	Not Applicable

Appendix 9-14: Relative Importance of Ecosystem Services – Soil Formation

Table 10c. The importance of the ecosystem service of soil formation

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								B: (all rows) The importance of this service to the production of goods may appear underrated due to the relatively low number goods produced by this service (despite the relatively high value of the goods). There is an indirect relationship between waste management and the production of goods (via maintenance of assets).
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								C: (all rows) Importance of this service was ranked as high for most biotic assets in this sheet because of their dependence on soil.
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							D: In areas of thin soil or high erosion, a small change in soil production could have a high impact on productivity; this effect would be less where natural soil f
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								
Cities & towns								C: Soil to support gardens, trees, or ornamental plants in settlements
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								
Mines & pits								
Industrial sites								
Reservoirs								
Canals								
Average Importance (1-3)		1.0	2.3	1.9	1.6	1.7	2.6	

Importance Values	
▨	Low (1)
▨	Medium (2)
■	High (3)
☐	Not Applicable

Appendix 9-15: Relative Importance of Ecosystem Services – Nutrient Cycling

Table 10c. The importance of the ecosystem service of nutrient cycling

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								C: (all rows) importance of this service was ranked as high for most biotic assets in this sheet because of their inherent dependence on nutrients
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							D: A small change in nutrient availability was deemed to have a potentially large impact on the economics of farming. Note that this does not apply to crops that receive all nutrients through artificial inputs.
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								C: Nutrients to support gardens, trees, or ornamental plants in settlements
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								C:, E: Primarily in the case of artificial nutrient cycling using industrial processes, potentially aided by natural processes.
Recreation-campgrounds and ski hills								C: Dependence on plants for most recreational activities in natural areas
Mines & pits								
Industrial sites								
Reservoirs								
Canals								
Average Importance (1-3)		1.0	2.5	2.1	2.1	2.0	2.2	

Importance Values	
■	Low (1)
■	Medium (2)
■	High (3)
□	Not Applicable

Appendix 9-16: Relative Importance of Ecosystem Services – Pollination

Table 10c. The importance of the ecosystem service of pollination

A: Assets		B: importance of ecosystem service to the production of goods	C: importance of ecosystem service to the maintenance of assets	D: importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass		▨	▨	▨	▨	▨	▨	
Northern wheat dry mixed grass		▨	▨	▨	▨	▨	▨	
Needle & thread sand grass - dry mixed grass		▨	▨	▨	▨	▨	▨	C: (all rows) Importance of this service was ranked as high for most biotic assets in this sheet because of their dependence on the service of pollination. This does not apply to wind pollinated plants or crops planted from seed.
Mixed grass		▨	▨	▨	▨	▨	▨	
Fescue grasslands		▨	▨	▨	▨	▨	▨	
Rocky mountain & parkland fescue		▨	▨	▨	▨	▨	▨	
Prairie treed & riparian cottonwood		▨	▨	▨	▨	▨	▨	
Prairie shrub		▨	▨	▨	▨	▨	▨	
Badlands & thin breaks		▨	▨	▨	▨	▨	▨	
Forest shrub		▨	▨	▨	▨	▨	▨	
Hardwood forest		▨	▨	▨	▨	▨	▨	
Mixed wood forest		▨	▨	▨	▨	▨	▨	
Spruce & fir forest		▨	▨	▨	▨	▨	▨	
Pine forest		▨	▨	▨	▨	▨	▨	
Cereal crops	Irrigated	▨	▨	▨	▨	▨		
Oilseeds and legumes		▨	▨	▨	▨	▨	▨	C,D: A small change in pollination was deemed to have a potentially large impact on the economics of farming.
Specialty crops		▨	▨	▨	▨	▨	▨	
Forage crops		▨	▨	▨	▨	▨	▨	
Cereal crops	Dryland	▨	▨	▨	▨	▨		
Oilseeds and legumes		▨	▨	▨	▨	▨	▨	
Forage crops		▨	▨	▨	▨	▨	▨	
Tame pasture		▨	▨	▨	▨	▨		
Lotic water (flowing)		▨	▨	▨	▨	▨	▨	
Lentic water (still)		▨	▨	▨	▨	▨	▨	
Forest wetlands		▨	▨	▨	▨	▨	▨	
Prairie wetlands		▨	▨	▨	▨	▨	▨	
Bare soil & rock		▨	▨	▨	▨	▨	▨	
Ice		▨	▨	▨	▨	▨	▨	
Roads & rails		▨	▨	▨	▨	▨	▨	
Rural/Ag residential		▨	▨	▨	▨	▨	▨	C: For gardens, trees, etc. E: Use of flowering ornamental plants and limiting the use of insecticides which may impact pollinators.
Cities & towns		▨	▨	▨	▨	▨	▨	
Wellsites		▨	▨	▨	▨	▨		
Pipelines, transmission & seismic lines		▨	▨	▨	▨	▨	▨	
Power Generation		▨	▨	▨	▨	▨		
Feedlots		▨	▨	▨	▨	▨		
Recreation-campgrounds and ski hills		▨	▨	▨	▨	▨	▨	
Mines & pits		▨	▨	▨	▨	▨	▨	
Industrial sites		▨	▨	▨	▨	▨		
Reservoirs		▨	▨	▨	▨	▨		
Canals		▨	▨	▨	▨	▨		
Average Importance (1-3)		1.6	2.1	1.6	1.5	1.6	1.7	

Importance Values	
▨	Low (1)
▨	Medium (2)
▨	High (3)
	Not Applicable

Appendix 9-17: Relative Importance of Ecosystem Services – Habitat/Refugia

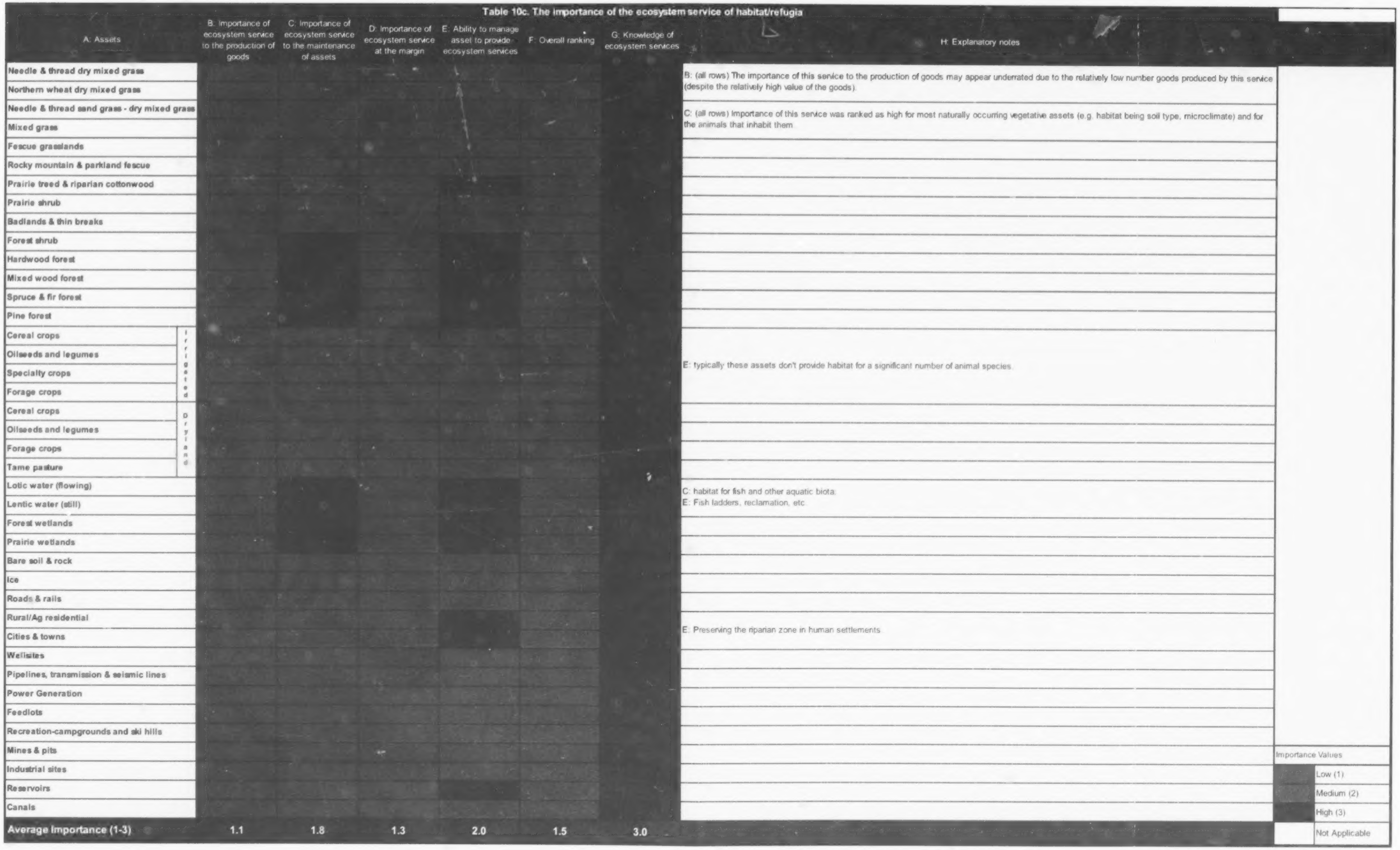


Table 10c. The importance of the ecosystem service of habitat/refugia

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								B: (all rows) The importance of this service to the production of goods may appear underrated due to the relatively low number goods produced by this service (despite the relatively high value of the goods).
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								C: (all rows) Importance of this service was ranked as high for most naturally occurring vegetative assets (e.g. habitat being soil type, microclimate) and for the animals that inhabit them.
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							E: typically these assets don't provide habitat for a significant number of animal species.
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								C: habitat for fish and other aquatic biota; E: Fish ladders, reclamation, etc.
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								E: Preserving the riparian zone in human settlements.
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								
Mines & pits								
Industrial sites								
Reservoirs								
Canals								
Average Importance (1-3)		1.1	1.8	1.3	2.0	1.5	3.0	

Importance Values

▨	Low (1)
▨	Medium (2)
▨	High (3)
☐	Not Applicable

Appendix 9-18: Relative Importance of Ecosystem Services – Primary Production

Table 10c. The importance of the ecosystem service of primary production

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass		■	■	■	■	■	■	C: (all rows) Importance of this service was ranked as high for most biotic assets in this sheet because of their inherent dependence on primary production.
Northern wheat dry mixed grass		■	■	■	■	■	■	
Needle & thread sand grass - dry mixed grass		■	■	■	■	■	■	E: Management function on these biotic assets is primarily the management of grazing, preservation of asset footprint, or in some cases reclamation.
Mixed grass		■	■	■	■	■	■	
Fescue grasslands		■	■	■	■	■	■	
Rocky mountain & parkland fescue		■	■	■	■	■	■	
Prairie treed & riparian cottonwood		■	■	■	■	■	■	
Prairie shrub		■	■	■	■	■	■	
Badlands & thin breaks		■	■	■	■	■	■	
Forest shrub		■	■	■	■	■	■	
Hardwood forest		■	■	■	■	■	■	D: Ranked higher at the margin due to potential economic impacts of reduced primary production
Mixed wood forest		■	■	■	■	■	■	
Spruce & fir forest		■	■	■	■	■	■	
Pine forest		■	■	■	■	■	■	
Cereal crops	Irrigated	■	■	■	■	■	■	
Oilseeds and legumes		■	■	■	■	■	■	
Specialty crops		■	■	■	■	■	■	
Forage crops		■	■	■	■	■	■	
Cereal crops	Dryland	■	■	■	■	■	■	
Oilseeds and legumes		■	■	■	■	■	■	
Forage crops		■	■	■	■	■	■	
Tame pasture		■	■	■	■	■	■	
Lotic water (flowing)		■	■	■	■	■	■	
Lentic water (still)		■	■	■	■	■	■	
Forest wetlands		■	■	■	■	■	■	
Prairie wetlands		■	■	■	■	■	■	
Bare soil & rock		■	■	■	■	■		
Ice		■	■	■	■	■		
Roads & rails		■	■	■	■	■		
Rural/Ag residential		■	■	■	■	■	■	C: Primary production to support gardens, trees, or ornamental plants in settlements
Cities & towns		■	■	■	■	■	■	
Wellsites		■	■	■	■	■	■	
Pipelines, transmission & seismic lines		■	■	■	■	■	■	
Power Generation		■	■	■	■	■		
Feedlots		■	■	■	■	■		C: Despite the requirement for feed (inevitably from primary production) this link was seen as indirect to feedlots and not assessed (see study methods)
Recreation-campgrounds and ski hills		■	■	■	■	■		C: Dependence on plants for most recreational activities in natural areas
Mines & pits		■	■	■	■	■		
Industrial sites		■	■	■	■	■		
Reservoirs		■	■	■	■	■	■	
Canals		■	■	■	■	■	■	
Average Importance (1-3)		1.9	2.4	1.4	2.0	1.9	2.7	

Importance Values	
■	Low (1)
■	Medium (2)
■	High (3)
☐	Not Applicable

Appendix 9-19: Relative Importance of Ecosystem Services – Water Supply

Table 10c. The importance of the ecosystem service of water supply

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								C: Dry grasses rely primarily on rainfall and are not highly dependent on overland flow.
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								C, D: Cottonwoods and other plants in the riparian zone are very sensitive to changes in the flow regime
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							F: Assets are highly dependent on irrigation and therefore water supply; D: A relatively small change in water supply could have a large effect in dry areas of the province and consequently impact the economics of farming.
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								D: Wetlands are very sensitive to changes in water regime.
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								
Cities & towns								
Wellsites								C: A reliable source of water is important to many industrial processes; E: Effective groundwater management with respect to industry (e.g. coalbed methane) commonly practiced in Southern Alberta.
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								
Mines & pits								
Industrial sites								
Reservoirs								
Canals								
Average Importance (1-3)		1.9	2.3	1.8	2.0	2.1	2.0	

Importance Values	
	Low (1)
	Medium (2)
	High (3)
	Not Applicable

Appendix 9-20: Relative Importance of Ecosystem Services – Food Production

Table 10c. The importance of the ecosystem service of food production

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								B: (all rows) The importance of this service to the production of goods may appear underrated due to the relatively low number goods produced by this service (despite the relatively high value of the goods).
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								E: Management of grazing
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							E: Management of crops and fish populations is well established
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								F: Importance due to gardens and fruit trees
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								
Mines & pits								
Industrial sites								
Reservoirs								E: Management of fish population
Canals								
Average Importance (1-3)		1.0	1.6	1.2	2.0	1.3	2.7	

Importance Values	
	Low (1)
	Medium (2)
	High (3)
	Not Applicable

Appendix 9-21: Relative Importance of Ecosystem Services – Raw Materials

Table 10c. The importance of the ecosystem service of raw materials

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass		■	■	■	■	■	■	B: (all rows) The importance of this service to the production of goods may appear underrated due to the relatively low number goods produced by this service (despite the relatively high value of the goods).
Northern wheat dry mixed grass		■	■	■	■	■	■	
Needle & thread sand grass - dry mixed grass		■	■	■	■	■	■	
Mixed grass		■	■	■	■	■	■	
Fescue grasslands		■	■	■	■	■	■	
Rocky mountain & parkland fescue		■	■	■	■	■	■	
Prairie treed & riparian cottonwood		■	■	■	■	■	■	
Prairie shrub		■	■	■	■	■	■	
Badlands & thin breaks		■	■	■	■	■	■	
Forest shrub		■	■	■	■	■	■	
Hardwood forest		■	■	■	■	■	■	E: Forest management practices are well established
Mixed wood forest		■	■	■	■	■	■	
Spruce & fir forest		■	■	■	■	■	■	
Pine forest		■	■	■	■	■	■	
Cereal crops	Irrigated	■	■	■	■	■	■	C: Reliance on fuels (raw material) for agriculture; F: the most important assets for raw materials were crops, forests, wellsites and mines
Oilseeds and legumes		■	■	■	■	■	■	
Specialty crops		■	■	■	■	■	■	
Forage crops		■	■	■	■	■	■	
Cereal crops	Dryland	■	■	■	■	■	■	
Oilseeds and legumes		■	■	■	■	■	■	
Forage crops		■	■	■	■	■	■	
Tame pasture		■	■	■	■	■	■	
Lotic water (flowing)		■	■	■	■	■	■	
Lentic water (still)		■	■	■	■	■	■	
Forest wetlands		■	■	■	■	■	■	
Prairie wetlands		■	■	■	■	■	■	
Bare soil & rock		■	■	■	■	■	■	E: Rock is used for limestone and cement production
Ice		■	■	■	■	■	□	
Roads & rails		■	■	■	■	■	□	C: Importance of aggregates, fuel, and other building materials for the built environment; D: Due to humans reliance on these raw materials and potential scarcity, a small change in availability could have a larger effect (e.g. extreme fuel prices)
Rural/Ag residential		■	■	■	■	■	□	
Cities & towns		■	■	■	■	■	□	
Wellsites		■	■	■	■	■	■	
Pipelines, transmission & seismic lines		■	■	■	■	■	■	
Power Generation		■	■	■	■	■	■	
Feedlots		■	■	■	■	■	■	
Recreation-campgrounds and ski hills		■	■	■	■	■	□	
Mines & pits		■	■	■	■	■	■	
Industrial sites		■	■	■	■	■	■	
Reservoirs		■	■	■	■	■	□	
Canals		■	■	■	■	■	□	
Average Importance (1-3)		1.5	1.9	1.5	1.9	1.6	2.8	

Importance Values	
■	Low (1)
■	Medium (2)
■	High (3)
□	Not Applicable

Appendix 9-22: Relative Importance of Ecosystem Services – Genetic Resources

Table 10c. The importance of the ecosystem service of genetic resources

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								B, C: (all rows) Genetic resources in the context of this project were taken to be the human use and manipulation of genetic material (e.g. genetically modified organisms for food). Therefore only goods and assets that are manipulated in this way are accounted for.
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								E: (all rows) These assets may provide genetic materials for "management" by humans, but are not typically maintained (column D) by the service.
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								C: Genetically modified or hybridized cattle
Recreation-campgrounds and ski hills								
Mines & pits								
Industrial sites								C,D,E: For industry specifically involved in the selective breeding or genetic modification of organisms
Reservoirs								
Canals								
Average Importance (1-3)		1.2	1.5	1.0	1.9	1.3	1.6	

Importance Values	
	Low (1)
	Medium (2)
	High (3)
	Not Applicable

Appendix 9-23: Relative Importance of Ecosystem Services – Aesthetic

Table 10c. The importance of the ecosystem service of aesthetic

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								B: (all rows) The importance of this service to the production of goods may appear underrated due to the relatively low number goods produced by this service (despite the relatively high value of the goods).
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								C: (all rows) The service of aesthetics provides enjoyment, but a secondary effect is the maintenance of highly valued (mostly) natural ecosystems via the aesthetic values providing motivation to protect aesthetically pleasing assets.
Mixed grass								
Fescue grasslands								E: (all rows) Primarily by leaving the assets in a natural state, but also through reclamation and restoration
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								E: Multiple uses of forested areas (including industry such as oil and gas) may occur while preserving most of the aesthetic values (e.g. Kananaskis country)
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								
Mines & pits								
Industrial sites								
Reservoirs								
Canals								
Average Importance (1-3)		1.0	2.3	1.0	2.3	1.5	2.2	

Importance Values	
	Low (1)
	Medium (2)
	High (3)
	Not Applicable

Appendix 9-24: Relative Importance of Ecosystem Services – Spiritual and Cultural Use

Table 10c. The importance of the ecosystem service of spiritual and traditional use

A: Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H: Explanatory notes
Needle & thread dry mixed grass								C: (all rows) Maintenance through the preservation of ecosystems resulting from the value endowed by traditional/spiritual use, or the use of traditional knowledge to actively preserve/maintain assets.
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								E: The ability to mange anthropogenic assets was not deemed as traditional knowledge.
Recreation-campgrounds and ski hills								
Mines & pits								
Industrial sites								
Reservoirs								
Canals								
Average Importance (1-3)		1.6	2.0	1.0	1.7	1.5	2.0	

Importance Values

■	Low (1)
■	Medium (2)
■	High (3)
☐	Not Applicable

Appendix 9-25: Relative Importance of Ecosystem Services – Science and Education

Table 10c. The importance of the ecosystem service of science and education

A. Assets		B: Importance of ecosystem service to the production of goods	C: Importance of ecosystem service to the maintenance of assets	D: Importance of ecosystem service at the margin	E: Ability to manage asset to provide ecosystem services	F: Overall ranking	G: Knowledge of ecosystem services	H. Explanatory notes
Needle & thread dry mixed grass								
Northern wheat dry mixed grass								E: (all rows) Primarily by protection of the assets (through education regarding their value) but also through reclamation and restoration.
Needle & thread sand grass - dry mixed grass								E: (all rows) Providing access to the asset for study or scientific manipulation.
Mixed grass								D: (all rows) A small change in science and education was not seen to have a large effect on any asset.
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								C: Research to prevent global warming.
Roads & rails								
Rural/Ag residential								
Cities & towns								
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								E: Campgrounds provide access to natural areas for education and science.
Mines & pits								
Industrial sites								
Reservoirs								
Canals								
Average Importance (1-3)		1.4	2.1	1.0	2.6	1.7	2.2	

Importance Values	
■	Low (1)
■	Medium (2)
■	High (3)
☐	Not Applicable

Appendix 9-26: Relative Importance of Ecosystem Services – Recreation

Table 10c. The importance of the ecosystem service of recreation

A. Assets		B. Importance of ecosystem service to the production of goods	C. Importance of ecosystem service to the maintenance of assets	D. Importance of ecosystem service at the margin	E. Ability to manage asset to provide ecosystem services	F. Overall ranking	G. Knowledge of ecosystem services	H. Explanatory notes
Needle & thread dry mixed grass								C: (all rows) The service of recreation provides enjoyment and health, but a secondary effect is the maintenance of highly valued (mostly) natural ecosystems via providing motivation to protect assets where people recreate.
Northern wheat dry mixed grass								
Needle & thread sand grass - dry mixed grass								E: (all rows) Typically the ability to manage various assets to prohibit or encourage recreation is quite high (e.g. trail closures), where recreation is not applicable, low values are assigned.
Mixed grass								
Fescue grasslands								
Rocky mountain & parkland fescue								
Prairie treed & riparian cottonwood								
Prairie shrub								
Badlands & thin breaks								
Forest shrub								
Hardwood forest								
Mixed wood forest								
Spruce & fir forest								
Pine forest								
Cereal crops	Irrigated							
Oilseeds and legumes								
Specialty crops								
Forage crops								
Cereal crops	Dryland							
Oilseeds and legumes								
Forage crops								
Tame pasture								
Lotic water (flowing)								
Lentic water (still)								
Forest wetlands								
Prairie wetlands								
Bare soil & rock								
Ice								
Roads & rails								
Rural/Ag residential								
Cities & towns								D: A small change in recreational opportunities may have a moderate impact on those leading sedentary lifestyles in cities and towns
Wellsites								
Pipelines, transmission & seismic lines								
Power Generation								
Feedlots								
Recreation-campgrounds and ski hills								C,D,E: These assets are inherently linked to recreation.
Mines & pits								
Industrial sites								
Reservoirs								C: More recreation was deemed to occur in reservoirs than canals
Canals								
Average Importance (1-3)		1.3	2.0	1.1	2.2	1.6	3.0	

Importance Values	
	Low (1)
	Medium (2)
	High (3)
	Not Applicable

Appendix 9-27: Goods Provided by Assets

	Native Prairie Assets									Forest Assets					Agricultural Assets					Aquatic Assets				Geologic Assets		Other Anthropogenic Assets										
Ecosystem Services	Needle & thread dry mixed grass	Northern wheat dry mixed grass	Needle & thread sand grass - dry mixed grass	Mixed grass	Fescue grasslands	Rocky mountain & parkland fescue	Prairie treed and riparian cottonwood	Prairie shrub	Badlands and thin breaks	Forest shrub	Hardwood forest	Mixed wood forest	Spruce & fir forest	Pine forest	Cereal	Oilseeds and Legumes	Specialty	Forage	Tame Pasture	Lentic water (flowing)	Lotic water (still)	Forest wetlands	Prairie wetlands	Bare soil & rock	Ice	Roads/rails	Rural residential/ Ag residential	City/town	Wellsites	Pipelines/transmission lines/seismic	Feedlots	Recreation- campgrounds and ski hills	Mines/pits	Industrial sites	Reservoirs	Canals
Primary Sector																																				
Agriculture - Crop/Vegetable															▨	▨	▨										▨									▨
Agriculture - Livestock	▨	▨	▨	▨	▨	▨	▨	▨		▨	▨	▨						▨	▨												▨					
Oil & gas	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨	▨	▨	▨			▨	▨		
Forestry											▨	▨	▨	▨																						
Mining	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨					▨	▨								▨	▨		
Subsistence (hunting, fishing, trapping, other)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				▨	▨	▨	▨	▨	▨	▨			▨								▨	▨
Secondary Sector																																				
Agriculture - Processing	▨	▨	▨	▨	▨	▨	▨	▨							▨	▨	▨	▨	▨								▨	▨			▨			▨		
Oil & gas refining																												▨		▨				▨		
Other manufacturing											▨	▨	▨	▨														▨		▨	▨		▨	▨		
Tertiary Sector																																				
Construction																											▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Transportation & utilities																				▨	▨					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Trade (wholesale/retail)											▨	▨	▨	▨	▨	▨	▨	▨	▨							▨	▨	▨	▨	▨	▨	▨	▨	▨		
Health & education																											▨	▨				▨				
Tourist services	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨						▨	▨	▨	▨	▨	▨	▨	▨	▨				▨			▨	
Government & non-profit																												▨	▨	▨	▨	▨	▨	▨		
Other services																												▨								
Cultural and Aesthetic																																				
Biodiversity	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				▨	▨	▨	▨	▨	▨				▨			▨		▨			▨	▨
Aesthetic	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				▨			▨	▨
Cultural	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				▨			▨	▨
Future options	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Non-market recreational opportunities	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨						▨	▨	▨	▨	▨	▨	▨	▨	▨		▨		▨			▨	▨

Applicable	▨
Not Applicable	

Appendix 9-27: Goods Provided by Assets

	Native Prairie Assets									Forest Assets					Agricultural Assets					Aquatic Assets				Geologic Assets		Other Anthropogenic Assets										
Ecosystem Services	Needle & thread dry mixed grass	Northern wheat dry mixed grass	Needle & thread sand grass - dry mixed grass	Mixed grass	Fescue grasslands	Rocky mountain & parkland fescue	Prairie treed and riparian cottonwood	Prairie shrub	Badlands and thin breaks	Forest shrub	Hardwood forest	Mixed wood forest	Spruce & fir forest	Pine forest	Cereal	Oilseeds and Legumes	Specialty	Forage	Tame Pasture	Lentic water (flowing)	Lotic water (still)	Forest wetlands	Prairie wetlands	Bare soil & rock	Ice	Roads/rails	Rural residential/ Ag residential	City/town	Wellsites	Pipelines/transmission lines/seismic	Feedlots	Recreation-campgrounds and ski hills	Mines/pits	Industrial sites	Reservoirs	Canals
Primary Sector																																				
Agriculture - Crop/Vegetable																																				
Agriculture - Livestock																																				
Oil & gas																																				
Forestry																																				
Mining																																				
Subsistence (hunting, fishing, trapping, other)																																				
Secondary Sector																																				
Agriculture - Processing																																				
Oil & gas refining																																				
Other manufacturing																																				
Tertiary Sector																																				
Construction																																				
Transportation & utilities																																				
Trade (wholesale/retail)																																				
Health & education																																				
Tourist services																																				
Government & non-profit																																				
Other services																																				
Cultural and Aesthetic																																				
Biodiversity																																				
Aesthetic																																				
Cultural																																				
Future options																																				
Non-market recreational opportunities																																				

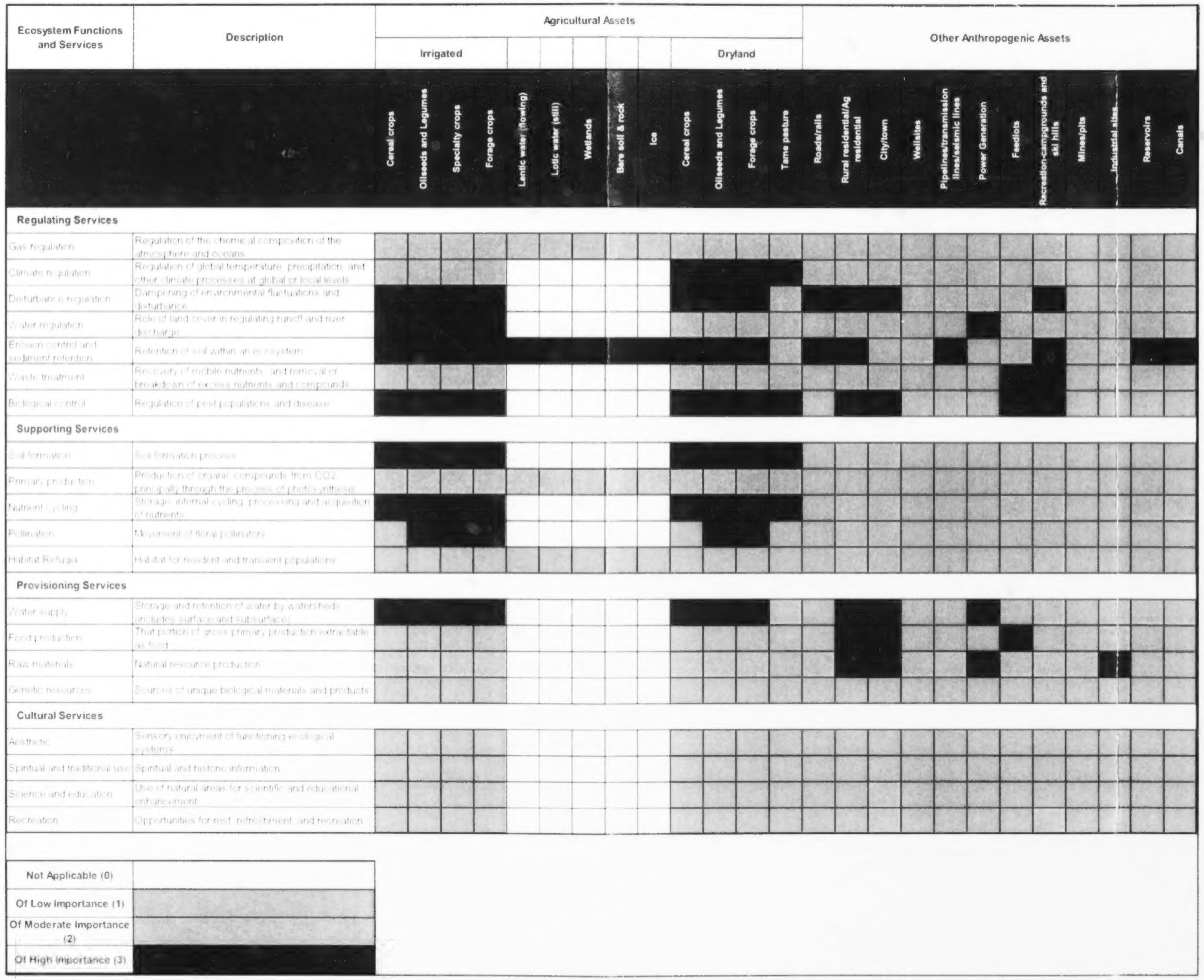
Applicable	
Not Applicable	

Appendix 9-28: Importance of Ecosystem Services at the Margin Relative to the Production of Goods

Ecosystem Functions and Services	Description	Agricultural Assets													Other Anthropogenic Assets											
		Irrigated									Dryland															
		Cereal crops	Oilseeds and Legumes	Specialty crops	Forage crops	Lentic water (flowing)	Lotic water (still)	Wetlands	Bare soil & rock	Ice	Cereal crops	Oilseeds and Legumes	Forage crops	Tame pasture	Roads/rails	Rural residential/Ag residential	City/town	Wellsites	Pipelines/transmission lines/seismic lines	Power Generation	Feedlots	Recreation-campgrounds and ski hills	Mines/pits	Industrial sites	Reservoirs	Canals
Regulating Services																										
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Disturbance regulation	Dampening of environmental fluctuations and disturbance	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Water regulation	Role of land cover in regulating runoff and river discharge	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Erosion control and sediment retention	Retention of soil within an ecosystem	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Biological control	Regulation of pest populations and disease	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Supporting Services																										
Soil formation	Soil formation process	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Primary production	Production of organic compounds from CO2, principally through the process of photosynthesis.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Pollination	Movement of floral pollinators	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Habitat/Refugia	Habitat for resident and transient populations	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Provisioning Services																										
Water supply	Storage and retention of water by watersheds (includes surface and subsurface)	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Food production	That portion of gross primary production extractable as food	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Raw materials	Natural resource production	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Genetic resources	Sources of unique biological materials and products	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Cultural Services																										
Aesthetic	Sensory enjoyment of functioning ecological systems	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Spiritual and traditional use	Spiritual and historic information	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Science and education	Use of natural areas for scientific and educational enhancement	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Recreation	Opportunities for rest, refreshment, and recreation	■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Not Applicable (0)	
Of Low Importance (1)	■
Of Moderate Importance (2)	■
Of High Importance (3)	■

Appendix 9-28: Importance of Ecosystem Services at the Margin Relative to the Production of Goods



Ecosystem Functions and Services	Description	Agricultural Assets													Other Anthropogenic Assets											
		Irrigated									Dryland															
		Cereal crops	Oilseeds and Legumes	Specialty crops	Forage crops	Lentic water (flowing)	Lotic water (still)	Wetlands	Bare soil & rock	Ice	Cereal crops	Oilseeds and Legumes	Forage crops	Tame pasture	Roads/rails	Rural residential/Ag residential	City/town	Wellsites	Pipelines/transmission lines/seismic lines	Power Generation	Feedlots	Recreation-campgrounds and ski hills	Mines/pits	Industrial sites	Reservoirs	Canals
Regulating Services																										
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels	▒	▒	▒	▒						■	■	■	■	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Disturbance regulation	Dampening of environmental fluctuations and disturbance	■	■	■	■						■	■	■	▒	■	■	■	▒	▒	▒	▒	■	▒	▒	▒	▒
Water regulation	Role of land cover in regulating runoff and river discharge	■	■	■	■						▒	▒	▒	▒	▒	▒	▒	▒	▒	■	▒	▒	▒	▒	▒	▒
Erosion control and sediment retention	Retention of soil within an ecosystem	■	■	■	■	■	■	■	■	■	■	■	■	▒	■	■	▒	▒	■	▒	▒	■	▒	▒	■	■
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	■	■	▒	▒	▒	▒
Biological control	Regulation of pest populations and disease	■	■	■	■						■	■	■	■	▒	■	■	▒	▒	▒	■	■	▒	▒	▒	▒
Supporting Services																										
Soil formation	Soil formation process	■	■	■	■						■	■	■	■	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Primary production	Production of organic compounds from CO2, principally through the process of photosynthesis	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	■	■	■	■						■	■	■	■	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Pollination	Movement of floral pollinators	▒	■	■	■						▒	■	■	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Habitat Refugia	Habitat for resident and transient populations	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Provisioning Services																										
Water supply	Storage and retention of water by watersheds (includes surface and subsurface)	■	■	■	■						■	■	■	▒	▒	■	■	▒	▒	■	▒	▒	▒	▒	▒	▒
Food production	That portion of gross primary production extractable as food	▒	▒	▒	▒						▒	▒	▒	▒	▒	■	■	▒	▒	▒	■	▒	▒	▒	▒	▒
Raw materials	Natural resource production	▒	▒	▒	▒						▒	▒	▒	▒	▒	■	■	▒	▒	■	▒	▒	▒	■	▒	▒
Genetic resources	Sources of unique biological materials and products	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Cultural Services																										
Aesthetic	Sensory enjoyment of functioning ecological systems	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Spiritual and traditional use	Spiritual and historic information	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Science and education	Use of natural areas for scientific and educational enhancement	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Recreation	Opportunities for rest, refreshment, and recreation	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒

Not Applicable (0)	
Of Low Importance (1)	▒
Of Moderate Importance (2)	▒
Of High Importance (3)	■

Appendix 9-29: Importance of Ecosystem Services at the Margin Relative to the Maintenance of Assets

Ecosystem functions and services	Description	Native Prairie Assets									Forest Assets					Agricultural Assets					Aquatic Assets				Geologic Assets	
		Needle & thread dry mixed grass	Northern wheat dry mixed grass	Needle & thread sand grass - dry mixed grass	Mixed grass	Fescue grasslands	Rocky mountain & parkland fescue	Prairie treed and riparian cottonwood complex	Prairie shrub	Badlands and thin breaks	Forest shrub	Hardwood forest	Mixed wood forest	Spruce & fir forest	Pine forest	Cereal crops	Oilseeds and Legumes	Specialty crops	Forage crops	Tame pasture	Lentic water (flowing)	Lotic water (still)	Forest wetlands	Prairie wetlands	Bare soil & rock	Ice
Regulating Services																										
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Disturbance regulation	Dampening of environmental fluctuations and disturbance	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Water regulation	Stabilization of hydrological flows	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Erosion control and sediment retention	Retention of soil within an ecosystem	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Biological control	Regulation of pest populations and disease	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Supporting Services																										
Soil formation	Soil formation process	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Primary production	Production of organic compounds from CO2, principally through the process of photosynthesis.	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Pollination	Movement of floral pollinators	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Habitat/Refugia	Habitat for resident and transient populations	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Provisioning Services																										
Water supply	Storage and retention of water by watersheds (includes surface and subsurface)	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Food production	That portion of gross primary production extractable as food	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Raw materials	Natural resource production	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Genetic resources	Sources of unique biological materials and products	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Cultural Services																										
Aesthetic	Sensory enjoyment of functioning ecological systems	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Spiritual and traditional use	Spiritual and historic information	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Science and education	Use of natural areas for scientific and educational enhancement	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■
Recreation	Opportunities for rest, refreshment, and recreation	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■

Not Applicable (0)	
Of Low Importance (1)	■
Of Moderate Importance (2)	■
Of High Importance (3)	■

Appendix 9-29: Importance of Ecosystem Services at the Margin Relative to the Maintenance of Assets

Ecosystem functions and services	Description	Native Prairie Assets									Forest Assets					Agricultural Assets					Aquatic Assets				Geologic Assets	
		Needle & thread dry mixed grass	Northern wheat dry mixed grass	Needle & thread sand grass - dry mixed grass	Mixed grass	Fescue grasslands	Rocky mountain & parkland fescue	Prairie treed and riparian cottonwood complex	Prairie shrub	Badlands and thin breaks	Forest shrub	Hardwood forest	Mixed wood forest	Spruce & fir forest	Pine forest	Cereal crops	Oilseeds and Legumes	Specialty crops	Forage crops	Tame pasture	Lentic water (flowing)	Lotic water (still)	Forest wetlands	Prairie wetlands	Bare soil & rock	Ice
Regulating Services																										
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels	■	■	■	■	■	■	■	■	▒	■	■	■	■	■						■	■	■	■	▒	■
Disturbance regulation	Dampening of environmental fluctuations and disturbance	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	▒	■	■	▒	▒
Water regulation	Stabilization of hydrological flows	▒	▒	▒	▒	▒	▒	■	▒	▒	▒	▒	▒	▒	▒						■	■	■	■	▒	▒
Erosion control and sediment retention	Retention of soil within an ecosystem	▒	▒	▒	▒	▒	▒	■	▒	▒	▒	▒	▒	▒	▒						■	▒	■	■	▒	▒
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						■	■	■	■	▒	▒
Biological control	Regulation of pest populations and disease	■	■	■	■	■	■	■	▒	▒	▒	▒	■	■	■						▒	▒	▒	▒	▒	▒
Supporting Services																										
Soil formation	Soil formation process	■	■	■	■	■	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒
Primary production	Production of organic compounds from CO2 principally through the process of photosynthesis	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						■	■	■	■	▒	▒
Pollination	Movement of floral pollinators	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒
Habitat Refugia	Habitat for resident and transient populations	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒
Provisioning Services																										
Water supply	Storage and retention of water by watersheds (includes surface and subsurface)	▒	▒	▒	▒	▒	▒	■	▒	▒	▒	▒	▒	▒	▒						▒	▒	■	■	▒	▒
Food production	That portion of gross primary production extractable as food	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒
Raw materials	Natural resource production	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒
Genetic resources	Sources of unique biological materials and products	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒
Cultural Services																										
Aesthetic	Sensory enjoyment of functioning ecological systems	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒
Spiritual and traditional use	Spiritual and historic information	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒
Science and education	Use of natural areas for scientific and educational enhancement	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒
Recreation	Opportunities for rest, refreshment, and recreation	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒						▒	▒	▒	▒	▒	▒

Not Applicable (0)	
Of Low Importance (1)	▒
Of Moderate Importance (2)	▒
Of High Importance (3)	■

Appendix 9-30: Ability to Manage Assets to Provide Ecosystem Services

Ecosystem Services	Description	Native Prairie Assets									Forest Assets					Agricultural Assets								Aquatic Assets				Geologic Assets		Other Anthropogenic Assets											
																Irrigated				Dryland																					
		Needle & thread dry mixed grass	Northern wheat dry mixed grass	Needle & thread sand grass - dry mixed grass	Mixed grass	Fescue grasslands	Rocky mountain & parkland fescue	Prairie treed & riparian cottonwood complex	Prairie shrub	Badlands and thin breaks	Forest shrub	Hardwood forest	Mixed wood forest	Spruce & fir forest	Pine forest	Cereal crops	Oilseeds & legumes	Specialty crops	Forage crops	Cereal crops	Oilseeds & legumes	Forage crops	Tame pasture	Lentic water (flowing)	Lotic water (still)	Forest wetlands	Prairie wetlands	Bare soil & rock	Ice	Roads & rails	Rural/Ag residential	Cities & towns	Wellsites	Pipelines/transmission lines/seismic lines	Power Generation	Feedlots	Recreation-campgrounds and ski hills	Mines & pits	Industrial sites	Reservoirs	Canals
Regulating Services																																									
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	□	□	□	□	□	□	■	□	□	□	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	■	■	■	■	■	■	□	■	■	□	□
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local	□	□	□	□	□	□	■	□	□	■	■	■	■	■	□	□	□	□	□	□	□	□	■	■	□	□	□	□	□	□	■	■	□	■	□	□	□	□	■	□
Disturbance regulation	Dampening of environmental fluctuations and disturbance	□	□	□	□	□	□	■	□	□	□	■	■	■	■	■	■	■	■	■	■	■	□	■	□	■	■	■	■	□	□	■	□	□	□	□	□	□	□	■	□
Water regulation	Stabilization of hydrological flows	□	□	□	□	□	□	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	■	■	□	□	■	□	□	□	□	■	■
Erosion control & sediment retention	Retention of soil within an ecosystem	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	■	□	■	■	■	■	■	□	□	■	■	■	■	■
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and	□	□	□	□	□	□	■	□	□	□	□	□	□	□	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	■	■	■	■	■	■	■	■	■	■	■
Biological control	Regulation of pest populations and disease	□	□	□	□	□	□	□	□	□	□	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	■	■	□	□	□	■	□	□	□	□	□
Supporting Services																																									
Soil formation	Soil formation process	□	□	□	□	□	□	□	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Primary production	Production of organic compounds from CO2, principally through the process of	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	□	□	□	□	□	□	■	□	□	□	□
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	■	■	□	□	□	■	□	□	□	□	□
Pollination	Movement of floral pollinators	■	■	■	■	■	■	□	□	□	□	□	□	□	□	□	■	■	■	□	■	■	□	□	□	□	□	□	□	□	■	■	□	□	□	□	□	□	□	□	□
Habitat/ Refugia	Habitat for resident and transient populations	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	■	■	■	■	■	□	□	■	■	■	□	□	□	□	■	□	□	■	■
Provisioning Services																																									
Water supply	Storage and retention of water by watersheds (includes surface and subsurface)	□	□	□	□	□	□	■	□	□	■	■	■	■	■	■	■	■	■	□	□	□	□	■	■	■	■	□	□	□	■	■	■	□	■	■	■	■	■	■	■
Food production	That portion of gross primary production extractable as food	■	■	■	■	■	■	□	□	□	■	■	■	□	□	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	■	■	□	□	□	■	□	□	□	■	□
Raw materials	Natural resource production	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	□	□	□	□	□	■	□	□	■	□	■	■	□	■	□	■	□	□	□
Genetic resources	Sources of unique biological materials and products	■	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Cultural Services																																									
Aesthetic	Sensory enjoyment of functioning ecological systems	■	■	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	□	■	■	■	■	■
Spiritual & traditional use	Spiritual and historic information	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	□	■	■	■	■	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Science & education	Use of natural areas for scientific and educational enhancement	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	■	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■	■
Recreation	Opportunities for rest, refreshment, and recreation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■	■	□	□	■	□	□	■	■	■	■	■	■	■	■	■	□	□	□	□	■	□	□	■	□

Low Ability to Manage or Not Applicable (1)	□
Moderate Ability to Manage (2)	■
High Ability to Manage (3)	■

Appendix 9-31: Knowledge of the Function and Process of Ecosystem Services Relative to Assets

Ecosystem functions and services	Description	Native Prairie Assets									Forest Assets					Agricultural Assets								Aquatic Assets				Geologic Assets		Other Anthropogenic Assets											
																Irrigated				Dryland																					
		Needle & thread dry mixed grass	Northern wheat dry mixed grass	Needle & thread sand grass - dry mixed grass	Mixed grass	Fescue grasslands	Rocky mountain & parkland fescue	Prairie treed and riparian cottonwood complex	Prairie shrub	Badlands and thin breaks	Forest shrub	Hardwood forest	Mixed wood forest	Spruce & fir forest	Pine forest	Cereal crops	Oilseeds and Legumes	Specialty crops	Forage crops	Cereal crops	Oilseeds and Legumes	Forage crops	Tame pasture	Lentic water (flowing)	Lotic water (still)	Forest wetlands	Prairie wetlands	Bare soil & rock	Ice	Roads/rails	Rural residential/Ag residential	City/town	Wellsites	Pipelines/transmission lines/seismic lines	Power Generation	Feedlots	Recreation-campgrounds and ski hills	Mines/pits	Industrial sites	Reservoirs	Canals
Regulating services																																									
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Climate regulation	Regulation of global temperature, precipitation, and other climate processes at global or local levels	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Disturbance regulation	Dampening of environmental fluctuations and disturbance	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Water regulation	Stabilization of hydrological flows	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Erosion control and sediment retention	Retention of soil within an ecosystem	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Waste treatment	Recovery of mobile nutrients, and removal or breakdown of excess nutrients and compounds	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Biological control	Regulation of pest populations and disease	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■	■	■	■	■	■
Supporting services																																									
Soil formation	Soil formation process	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	■	■	■	■	■	■	■	■	■	□	■	■	■	■	■	■
Primary production	Production of organic compounds from CO2, principally through the process of photosynthesis.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	■	■	■	■	□	□	□	□	□	■	■
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	■	■	□	■	■	■	■	■	■	■	■
Pollination	Movement of floral pollinators	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■	■	■	□	■	■	□	■	■	■	■	■	■	■	■	■	□	■	□	□	■	■	□	□	□
Habitat/Refugia	Habitat for resident and transient populations	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Provisioning services																																									
Water supply	Storage and retention of water by watersheds (includes surface and subsurface)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■	□	■	■	■	■	■	■	■	■	■	■	■
Food production	That portion of gross primary production extractable as food	■	■	■	■	■	■	□	□	□	□	□	□	□	□	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	■	□	□	□	□	■	□	□	□	■	□
Raw materials	Natural resource production	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	■	■	■	■	□	■	■	□	□
Genetic resources	Sources of unique biological materials and products	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	□	□	□	□	■	□	□	□	□	□
Cultural Services																																									
Aesthetic	Sensory enjoyment of functioning ecological systems	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Spiritual and traditional use	Spiritual and historic information	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Science and education	Use of natural areas for scientific and educational enhancement	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Recreation	Opportunities for rest, refreshment, and recreation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	□	□	□	■	□	□	■	■

Not Applicable (0)	□
Low Understanding/ Availability (1)	■
Moderate Understanding/	■
High Understanding/ Availability (3)	■

Note: Services that did not apply to a given asset were marked as not applicable. If the knowledge of a function on an asset was ranked as low, this was meant to imply that more research into the interaction would benefit southern Alberta.